RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)							DATE February 2003	
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research			R-1 ITEM NOMENCLATURE Computing Systems and Communications Technology PE 0602301E, R-1 #12					
COST (In Millions)	FY 2002	FY2003	FY2004	FY2005	FY2006	FY2007	FY2008	FY2009
Total Program Element (PE) Cost	349.666	409.256	404.859	479.119	561.272	625.538	691.431	701.221
Intelligent Systems and Software ST-11	88.586	50.980	43.755	43.736	55.775	74.261	81.022	77.041
High Performance and Global Scale Systems ST-19	139.101	121.242	71.047	47.566	0.000	0.000	0.000	0.000
Information Assurance and Survivability ST-24	65.204	44.892	44.459	44.898	69.474	73.283	87.855	87.768
Asymmetric Threat ST-28	56.775	77.034	79.114	80.878	91.284	107.190	119.580	119.513
Language Translation ST-29	0.000	43.432	57.201	55.883	65.767	65.945	66.196	65.826
Cognitive Systems Learning and Perception ST-30	0.000	10.595	14.822	58.846	102.743	122.139	117.140	107.272
Communications, Interaction and Cognitive Networks ST-31	0.000	29.264	42.177	54.433	56.069	49.833	58.570	58.512
Cognitive Systems Foundations ST-32	0.000	13.528	25.833	58.552	61.450	73.283	78.094	82.892
Knowledge Representation and Reasoning ST-33	0.000	18.289	26.451	34.327	58.710	59.604	82.974	102.397

(U) Mission Description:

(U) The Computing Systems and Communications Technology program element is directed toward the application of advanced, innovative computing systems and communications technologies. Cognitive Information Processing Technology will be the next revolution in computing and information processing. The technology will allow computational systems to have reasoning and learning capabilities and levels of autonomy far beyond those of today's systems. With the ability to reason, learn, and adapt, and with facilities for self-awareness, these will literally be

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systems that know what they are doing, enabling new levels of capability and powerful new applications. Encompassed in this technology push area are four new projects: Cognitive Systems Learning, Communication and Interaction Technology, Cognitive Systems Foundation, and Knowledge Representation and Computational Perception.

(U) The Intelligent Systems and Software project develops and applies new software development, processing and database management technology to produce, store, and analyze information about battle space operations. It facilitates information production by developing fundamental new techniques to transform data into descriptions of objects. It facilitates the design of complex Command, Control, Communication and Computation Intelligence, Surveillance and Reconnaissance (C4ISR) systems by formalizing descriptions of semantics, performance, and resource levels, and developing design tools to use those formalisms to assemble systems.

(U) The High Performance and Global Scale Systems project develops the computing, networking, and associated software technology base underlying the solutions to computational and information-intensive applications for future defense and federal needs. These technologies will lead to successive generations of more secure, higher performance, and more cost-effective microsystems, associated software technologies, advanced mobile information technology and prototype experimental applications critical to defense operations.

(U) The Information Assurance and Survivability project is developing the technology required to make emerging information system capabilities (such as wireless and mobile code/mobile systems) inherently secure, and to protect DoD's mission-critical systems against attack upon or through the supporting information infrastructure. These technologies will enable our critical systems to provide continuous correct operation even when they are attacked, and will lead to generations of stronger protection, higher performance, and more cost-effective security and survivability solutions scalable to several thousand sites.

(U) The Asymmetric Threat project addresses one of our Nations' most serious threats. It is not the threat of a conventional, force-on-force engagement by an opposing military, but instead, the threat of an unconventional yet highly lethal attack by a loosely organized group of transnational terrorists or other factions seeking to influence U.S. policy. This new threat brings new technological challenges to the U.S. The U.S. will need to develop technology to detect, identify, classify, and track small, shadowy, hard to define and identify, and loosely organized terrorist groups as they plan adverse actions against the U.S. This new threat will have a smaller mass, exhibit fewer observables, and yet will be more lethal in consequence. Sparse activity that was once too insignificant to notice will need to be detected, correlated, and understood. This can only be achieved by developing a new level of automation to detect, correlate, and understand all of the observable evidence exhibited by these sparse events.

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(U) The newly established Language Translation project will develop and apply new software database management and human computer interaction technologies to provide fundamentally new capabilities of critical importance for a wide range of national security needs. This will enable advanced information technology to (a) automatically exploit large volumes of speech and text in multiple languages; (b) revolutionize human-computer interaction via using spoken and written English and foreign languages; (c) more effectively accomplish computing and decision-making tasks in stressful, time sensitive situations; and (d) become active, autonomous agents/assistants to the warfighter by collecting, filtering, synthesizing and presenting information in a timely and relevant form.

(U) The Cognitive Systems Learning and Perception project will develop technologies that enable systems to learn and draw on their accumulated experience by applying knowledge gained through such experience to improve performance. These technologies will lead to systems demonstrating increased self-reliance, self-adaptive reconfiguration, intelligent negotiation, cooperative behavior, and survivability with reduced human intervention. Cognitive systems will comprise three primary types of processes: reactive, deliberative and reflective. Each of these will be improved through experiential learning.

(U) The Communications, Interaction and Cognitive Networks project will dramatically improve warfighter effectiveness by developing revolutionary methods for users to interact with and direct cognitive systems (and the physical sensors and effectors they control) and for large-scale collections of cognitive systems to interact with one another in support of user objectives. Specifically, this project will develop technologies for creating systems capable of instruction, guidance, and persuasion using all forms of natural communication; technologies enabling systems to detect and assess the user's cognitive state and adapt to optimize understanding and effectiveness of the user; and high-level languages for rapid but precise specification of complex behavior in response to mission demands, such as configuration of sensor networks.

(U) The Cognitive Systems Foundations project will develop novel system-level solutions through the intelligent integration of cognitive capabilities built on robust software and hardware infrastructure. Systems with humanlike capability will integrate the cognitive capabilities of reasoning, learning, explaining, ability to be advised, self-awareness and coping robustly with surprise. These aspects of intelligence will be combined in innovative and powerful ways using new cognitive architectures. Overall this element seeks to make fundamental scientific and mathematical improvements in our understanding of and ability to create information and computing systems.

(U) The Knowledge Representation and Reasoning project is central to the creation of a new class of computational systems – Cognitive Computing Systems. These novel computer-based systems will reason, learn, and respond intelligently to things that have not been previously programmed or encountered. This will be accomplished by creating unique and powerful new abilities for computers to perceive and understand

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the world, and to reason intelligently with the results of this kind of perception. This program will develop novel and effective technologies for representing knowledge of the world in computer-processable form. This project focuses on two groundbreaking research areas that will develop core cognitive capabilities essential to a cognitive information processing system.

(U) Program Change Summary: *(In Millions)*

	FY 2002	FY 2003	FY 2004	FY2005
Previous President's Budget	358.494	424.940	410.808	399.724
Current President's Budget	349.666	409.256	404.859	479.119
Total Adjustments	-8.828	-15.684	-5.949	79.395
Congressional program reductions	0.000	-16.184		
Congressional increases	0.000	+0.500		
Reprogrammings	-7.720	0.000		
SBIR/STTR transfer	-1.108	0.000		

(U) Change Summary Explanation:

FY 2002	Decrease reflects SBIR transfer and below threshold reprogrammings.
FY 2003	Decrease reflects congressional program and undistributed reductions, offset by an add for the Center for Critical Languages.
FY 2004	Reprioritization of Agency requirements, transfer of several programs to PE 0602702E, Project TT-13, and the net result of completing High Performance Computing programs, offset by initiation of Cognitive Information Processing efforts.
FY 2005	Expanded Agency emphasis in the new Cognitive Information Processing Technology thrust area.

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COST (In Millions)	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Intelligent Systems and Software ST-11	88.586	50.980	43.755	43.736	55.775	74.261	81.022	77.041

(U) Mission Description:

(U) This project develops and applies new technology for software development, processing and database management for systems that produce, store, and analyze information about battlespace operations. It facilitates information production by developing fundamentally new techniques to transform signals into descriptions of battlespace entities, to exchange information about entities among different systems at both the syntactic and semantic levels, and to manage that information exchange as situations and resources change over time. These technologies lead to two payoffs. First, they accelerate the design of complex Command, Control, Communications and Computation Intelligence, Surveillance and Reconnaissance (C^4ISR) systems by formalizing descriptions of semantics, performance, and resource levels, and developing design tools to use those formalisms to assemble systems. Second, they enable field integration of legacy systems by providing general-purpose tools that use these formalisms to search for, browse, display, and combine services available to a command center, especially in coalition environments.

(U) In an effort to more accurately reflect programs by function, several programs previously budgeted in project ST-11 have shifted to other projects in PE 0602301E. The Situation Presentation and Interaction program and the Automated Speech to Text Exploitation programs are now funded in a new project entitled "Language Translation" (ST-29). Similarly, the Composable High Assurance Trusted Systems program is now funded under project ST-24.

(U) Program Accomplishments/Planned Programs:

	FY 2002	FY 2003	FY 2004	FY 2005
Situation Presentation and Interaction	15.901	0.000	0.000	0.000

(U) The Communicator program created a dialog-based information interface that allows warfighters to acquire theater information, order logistical support, or obtain mission planning execution information without the need for a second human in the information loop. The dialog-based system has a scalable interface that allows the warfighter to accomplish the tasks (e.g. receive orders, resupply, identify the threat unit to their immediate front) regardless of skill level. Communicator delivered proof of concept prototypes of a dialog-based logistics ordering system

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for the USMC (logistics management at the tactical level), a maintenance assistant for F-18 ground crews at Patuxent NAS, and a shipboard command and control and status system for the USS SEA SHADOW. Further maturation of these prototypes will be accomplished in Symphony, a follow-on program to Communicator.

(U) The Babylon program is providing the tactical warfighter with real-time, face-to-face speech translation during combat and humanitarian operations in foreign territories. The program addresses domain-specific translation accuracy and response time. Early versions of Babylon technology relying on simple dictionaries and phrases have been deployed on a test basis to Afghanistan. Future versions will offer more sophisticated, flexible and fluid translation capability that will be more robust and conducive to normal human conversations.

(U) Situation Presentation and Interaction thrusts are funded in Project ST-29 beginning in FY 2003.

(U) Program Plans:

- Communicator.
  - -- Finalized and presented evaluation protocols and metrics for heterogeneous human computer dialog systems to the dialog and speech communities.
  - -- Transitioned Communicator technology to services based on proof of concept results, e.g., transition Communicator prototype to USMC for continued refinement and limited production in support of the Small Unit Logistics ACTD and the Commandants Warfighter Laboratory at Marine Corps Base Quantico.
  - -- Defined and published final (release) version of the Galaxy-Communicator 4.0 hub architecture for general use in the dialog systems development community.
  - -- Finished evaluation of commercial "smart-phone" technology vs. military-specific prototypes for cost, ruggedness, and other selection-based criteria.
  - -- Conducted proof of concept demonstration of Communicator technology on the USS SEA SHADOW and with F-18 maintenance crews.
  - -- Evaluated a follow-on research program for dialog systems.
  - -- Promoted standardization with the Galaxy-Communicator architecture through the World-Wide-Web-Consortium Voice Browser Group (W3C-VB).
  - -- Published specification of the multi-modal Galaxy-Communicator architecture.

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- Babylon.
  - -- Establish baseline hardware design for handheld translation technology.
  - -- Upgrade DARPA one-way technology to limited two-way translation.
  - -- Obtain initial software decision approvals for full-featured DARPA two-way translation.
  - -- Conduct multi-lingual data collection in Pashto, Dari, Farsi, Arabic, and Mandarin for contingency operations.
  - -- Produce prototype handheld devices for field evaluations and acceptance.
  - -- Perform initial coordination with U.S. Army PM Soldier for software integration into land warrior Block III (version 3.0).
  - -- Integrate speech recognition engines into natural language parsers and translators.
  - -- Distribute multilingual corpus to R&D community.
  - -- Deliver upgraded handhelds (capable of supporting two-way technology) to software developers.
  - -- Deliver alpha versions of DARPA two-way software for initial user testing.
  - -- Select set of foreign languages for final development.
  - -- Populate language digital resource repository at Defense Language Institute (DLI).

	FY 2002	FY 2003	FY 2004	FY 2005
Automated Speech and Text Exploitation	27.831	0.000	0.000	0.000

(U) The Translingual Information Detection, Extraction and Summarization (TIDES) program is revolutionizing the way time-critical intelligence is obtained from speech and text by developing technology to enable English-speaking operators and analysts to exploit the huge amounts of foreign speech and text available electronically but currently unexploitable due to vast volumes and insufficient foreign language skills. TIDES is creating powerful new capabilities for Detection (finding or discovering needed information), Extraction (pulling out key information), Summarization (substantially shortening what a user must read), and Translation (converting foreign language material to English). This will dramatically increase the quantity, quality, and timeliness of analysis and reporting, providing vital information to senior decision makers and enabling commanders to project U.S. power and protect U.S. forces around the globe.

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(U) The Effective Affordable Reusable Speech-To-Text (EARS) program is creating new automatic speech-to-text transcription technology whose output is substantially richer and much more accurate than currently possible. EARS will provide passive listening technology for critical languages and media for a wide range of national security applications. It will enable effective automated transcription from both broadcasts and telephone conversations.

(U) Beginning with FY 2003, Automated Speech and Text Exploitation programs are funded in project ST-29.

(U) Program Plans:

- Translingual Information Detection, Extraction and Summarization (TIDES).
  - -- Demonstrate capability to detect and track events described in English and Chinese news sources.
  - -- Create an initial capability to process Arabic text and audio sources.
  - -- Demonstrate capability to extract key information (about people, places, organizations, and relationships) from English sources.
  - -- Conduct an initial evaluation of machine translation technology.

- Effective Affordable Reusable Speech-To-Text (EARS).
  - -- Launched effort to develop automatic techniques to produce rich, readable transcripts of broadcasts and telephone conversations in English, Chinese, and Arabic.

	FY 2002	FY 2003	FY 2004	FY 2005
Software for Situational Analysis	14.026	18.313	6.055	0.000

(U) Two complementary efforts are budgeted in the Software for Situation Analysis component: Rapid Knowledge Formation (RKF), and High Precision Knowledge Formation (HPKF).

- The Rapid Knowledge Formation program enables subject matter experts who are not Artificial Intelligence experts to build, share, and reuse large knowledge bases. RKF is developing technologies that will be evaluated in challenge problem experiments in tactical ground combat. Technology challenges include direct knowledge entry by non-programmers, coordinating entry of possibly overlapping and inconsistent knowledge by geographically distributed individuals, and achieving a knowledge entry rate without AI training of twice that

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of today's AI expert, which also results in an enormous and comprehensive knowledge base (10^6 axioms). Knowledge entry R&D is focused on techniques for natural language user input into statements of logic as well as to repair and clarify knowledge base entries. Knowledge coordination focuses upon generating new axioms by such techniques as reasoning by analogy and reasoning by example, and on techniques for combining sets of axioms developed by possibly different sources into larger consistent modules. The large knowledge bases created by RKF are needed for such complex problems as the detection and identification of evasive and concealed targets, offensive and defensive information operations, and WMD capability assessments of terrorist organizations. By the end of the RKF program, a number of sets of knowledge engineering and development tools will be provided to DoD and government organizations to be incorporated into their intelligence and warfare analysis systems. The RKF technology will then enable "deeper" reasoning by intelligent system, allowing automation to support precision target identification, nomination, and engagement.

- The High Precision Knowledge Formation initiative will develop tools to build rich, complex, highly specialized knowledge bases needed to support precision tactical operations. Ground warfare tactics exhibit great variety and complexity, and depend greatly on complex relationships between natural and man-made elements of the battlefield. HPKF will develop tools to construct, maintain, and update knowledge about terrain features, mobility factors, sensor characteristics, weapons effects, and engagement tactics in combat situations ranging from desert warfare through infantry operations in jungle to urban combat. It will enable automated forces and planning systems to achieve precision engagement of hostile ground forces, both mechanized and dismounted.

(U) Program Plans:

– Rapid Knowledge Formation.
  -- Develop very large Predictive Battlespace Awareness (PBA) knowledge bases in coordination with end users.
  -- Provide the capability to represent KB inconsistencies and uncertainty in a manner that can be understood by subject matter experts rather than only by AI experts.
  -- Improve reliability and operability of knowledge entry and query tools to support transition to an operational environment.

– High Precision Knowledge Formation (HPKF).
  -- Evaluate ability of 1 mega-axiom knowledge base to support high-fidelity problem solving methods for situation awareness and tactical command and control.
  -- Define tactical air/ground combat challenge problem, select external decision aids, and prototype export/import of knowledge with those aids.

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	FY 2002	FY 2003	FY 2004	FY 2005
DARPA Agent Markup Language (DAML)	15.856	21.760	12.000	2.594

(U) The DARPA Agent Markup Language (DAML) program is developing military software tools for use on IntelLink and other emerging collaborative Command and Control systems. The program focuses on technologies 1) to enhance interoperability, 2) to extend the reach of the World Wide Web to programs, sensors, and other data sources, and 3) to enable agent-based programs to share information through these mechanisms. DAML will develop a software language that ties the information about a web resource to machine-readable semantics (ontology), describing both data contents and service providers. DAML will be demonstrated in operational environments, including both the intelligence community (IntelLink) and control of tactical military operations. This effort will provide new technologies for the intelligent integration of information across a wide variety of heterogeneous military sources and systems in real time. In addition, its work on semantic mapping has enabled the development of a set of tools to transform existing intelligence and command/control software to operate in network-centric computing environments, using DAML ontologies and service descriptions. These tools will correlate application-specific ontologies to shared database schema, construct translators from application data structures to database schema, and build mediators that convert product streams from publishers to subscribers. The tools will be prototyped and evaluated within existing C^4ISR support systems that contain high data-rate signal processing, sensor exploitation, and engagement planning applications, and be released as a DARPA Intelligent Software Toolkit (DIST).

(U) Program Plans:

- Perform experimental analysis on and deploy IntelLink DAML Briefing and Search Tools on operational IntelLink node.
- Demonstrate and prototype DAML tools for web applications for the Military and National Intelligence Community.
- Conduct experimental analysis of DAML applications and deploy DAML tools for joint and component command and control interoperability for major commands such as Joint Forces Command (JFCOM).
- Prototype DAML tools as support to enhance the use of agents for coalition warfare command and control.
- Prototype suite of additional tools to encapsulate legacy software to support DAML ontologies, logics, and service descriptions.
- Build example mediators to convert data among DAML ontologies, referencing external knowledge bases as necessary.
- Transition DAML language Service and Rule specifications to the World Wide Web Consortium (W3C) for acceptance for commercial and civilian use.

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	FY 2002	FY 2003	FY 2004	FY 2005
Taskable Agent Software Kit (TASK)	5.617	10.907	5.490	0.000

(U) The Taskable Agent Software Kit (TASK) program will develop tools for the construction and analysis of multi-agent systems that realize a global objective through local decisions based on embedded models of the mission, the environment, and interaction with other agents. These synthesis and analysis tools will provide a sound, common engineering foundation for the development and deployment of high confidence agent-based computing solutions to a spectrum of military problems requiring robust, scalable, decentralized approaches in dynamically changing environments. While many agent-based systems are currently being built to support militarily relevant applications such as information retrieval and logistics, development methods are ad hoc and little is understood about how to engineer desirable global behaviors from local, autonomous actions and decisions or about how to mitigate and contain potentially undesirable emergent behaviors, particularly in highly dynamic and uncertain environments. This effort will explore methods derived from Control Theory, Decision Theory, and Operations Research for correctly modeling and building agent-based systems. Experiments will reveal the qualitative aspects of environments that favor the use of agent-based systems over conventional, centralized approaches.

(U) Program Plans:

- Publish initial design and analysis techniques in two focus domains: (a) control and analysis of autonomous vehicles in dynamic environments and (b) decentralized, competitive resource allocation for logistics.
- Establish a consolidated open experimental framework based on cooperative autonomous vehicles for integration and evaluation of agent control, coordination, learning, and adaptation algorithms and analysis techniques.
- Demonstrate and evaluate agent design and analysis techniques on a series of challenge problems characterized by increasing mission complexity (search to surveillance to targeting), increasing scale (10s to 100s of vehicles), and increasing environment uncertainty (dynamic target behavior to vehicle failures to malicious vehicle behavior).
- Deploy a prototype suite of integrated agent-creation tools with predictable behaviors based on mathematical techniques for modeling and analyzing agent behavior.

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	FY 2002	FY 2003	FY 2004	FY 2005
Composable High Assurance Trusted Systems (CHATS)	7.355	0.000	0.000	0.000

(U) The Composable High Assurance Trusted Systems (CHATS) program is developing the tools and technology that will enable core network services to be protected from the introduction and execution of malicious code or other attack techniques and methods. These tools and technologies will provide the security services needed to achieve comprehensive-secure, highly distributed, mission-critical information systems for the DoD. A unique feature of CHATS is that these system capabilities will be developed by engaging the open-source community in security functionality for existing open-source operating systems. Additionally, DARPA will engage the open-source community in a consortium-based approach to create a "neutral", secure operating system architecture framework. This security architecture framework will then be used to develop techniques for composing operating system capabilities to support both servers and clients in the increasing network-centric communications fabric of the DoD. In FY 2003 the CHATS program is funded under project ST-24 in this program element.

(U) Program Plan:

- Develop an operational prototype of the Composable High Assurance Trusted System.
- Develop operational capability of candidate high assurance trusted implementation language and tools.
- Validate CHATS for resistance to malicious code and other system attack techniques and methods.
- Investigate the range and alternative high value applications and services needed and required to interoperate with the composable high assurance technology.
- Develop protection profiles for the preferred applications and services.
- Investigate alternative approaches to lifecycle management for the high assurance trusted operating systems technology; identify the best alternatives.

	FY 2002	FY 2003	FY 2004	FY 2005
Automatic Target Recognition Technology	0.000	0.000	8.000	14.714

(U) The Automatic Target Recognition Technology program will develop new sensor exploitation aids to detect targets in high volume sensor data with minimal human support. It will support very large sets of targets (1000's of target types) with high identification performance and very

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low false alarm rates. It will develop modeling methods to account for target variability, caused by partial damage, design difference, or equipment loaded onto the exterior of the vehicle. The program will support interaction with humans to supply operational context, guide hypothesis development, and adapt models. By developing techniques for in-the-field training of models, signatures, and scoring parameters, it will identify vehicle-specific signatures, and develop new target fingerprinting techniques. Finally, new methods to assist humans achieve precise identification of ad hoc; poorly defined targets will be developed. The program supports rapid and accurate detection, recognition, and identification of targets in high volume sensor imagery. It will enable a dramatic reduction in sensor-to-shooter timelines, supporting dynamic target engagement. The technology objective is to make possible autonomous hunter-killer weapon concepts that will reduce manpower burdens and delays by reducing requirements for human analysis of sensor data, while dramatically increasing targeting flexibility.

(U) Program Plans:

- Obtain a regular supply of data from field and developmental sensors, covering many target types in many environmental settings.
- Obtain or estimate ground truth for those data to provide a foundation for periodic performance assessments.
- Extend existing performance analyses to provide bounds on detection, identification, and fingerprinting performance for 1000's of vehicle types, including some that cannot be modeled a priority.
- Develop model generation, model update, detection, recognition, identification, and fingerprinting algorithms based on a range of technical approaches.
- Periodically assess technologies on the field data, computing statistically significant estimates of performance to compare against the performance analyses.

	FY 2002	FY 2003	FY 2004	FY 2005
Information Dissemination and Management	0.000	0.000	6.210	14.714

(U) The Information Dissemination and Management Program develop technology to allocate information resources (transmission, storage, and processing) for optimal utilization of data across multiple missions. Techniques will be developed that will adjust information flows to fit available bandwidth/time for bulk data such as target imagery (by adjusting quality, data rate, and time of transmission), streaming data, such as video, GMTI (by adjusting quality and rate) and command data, such as waypoints, events (by adjusting time of transmission). The program will explore approaches to the reallocation of resources dynamically as tasks arise and network topology and capabilities change, through the use of intermediate storage or intermediate processes (e.g. registration). The program provides real-time sensor-to-shooter resource management to support dynamic operations, including targeting, force protection, and battlespace awareness. Most importantly it will provide information for use

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by commanders and weapons when communications resources are oversubscribed during battle conditions, and provide the means to respond in real-time to changes in resources due to outages or battle damage.

(U) Program Plans:

- Work with service partners to identify and obtain a suitable testbed, with supporting data links, databases, application servers, and users.
- Define an information architecture that establishes insertion constraints for information management technology.
- Develop and extend real-time resource allocation technology to manage network assets in response to time-varying demands.
- Develop human interfaces to allow controllers to specify information needs and anticipate future demands.
- Insert information management algorithms into the testbed, and stimulate them with increasing levels of subscription.

	FY 2002	FY 2003	FY 2004	FY 2005
Rapid Software Composition for Embedded Systems	0.000	0.000	6.000	11.714

(U) The Rapid Software Composition for Embedded Systems program develops technology to permit rapid assembly of heterogeneous C^4ISR components for execution on complex, highly parallel real time embedded architectures. It will explore techniques to permit rapid parallel code development and optimization to leverage advanced architectures for development, exploration and rapid deployment of C^4ISR components. This program will provide tools and software libraries that allow C^4ISR systems to be rapidly assembled from discrete, protested components. It will assist developers tailor C^4ISR systems to be assembled for mission-specific tasks. In addition, the technology will facilitate mapping C^4ISR system components onto advanced run time architectures for high performance operations in limited footprint environments (airborne, tactical vehicle, afloat). Its tools will rapidly develop and optimize new C^4ISR capabilities using spiral development processes without loss of performance.

(U) Program Plans:

- Identify a set of challenge applications across the spectrum of C^4ISR missions.
- Assemble a library of kernal algorithm components.
- Map the kernels onto representative hardware architectures.
- Develop input/output/state descriptions of each kernel, as mapped to each architecture.

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- Construct tools to assemble kernels into systems, including data flows and process/processor assignments.
- Build predictive models of systems assembled from kernels to verify run-time feasibility and achievement of desired performance.
- Validate the tools and models within the challenge applications.

	FY 2002	FY 2003	FY 2004	FY 2005
Reuse Technology Adoption Program (RTAP)	2.000	0.000	0.000	0.000

(U) The Reuse Technology Adoption Program (RTAP) focused on research strategies for multi-agent system technology and transition results to accomplish software reuse.

(U) Program Plans:
- Explored peer-to-peer communication models in context of military requirements.
- Experimented with technologies for developing/evolving coalitions of software components.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
High Performance and Global Scale Systems ST-19	139.101	121.242	71.047	47.566	0.000	0.000	0.000	0.000

(U) Mission Description:

(U) This project develops the computing, networking, and associated software technology base underlying the solutions to computational and information-intensive applications for future defense and federal needs. These technologies will lead to successive generations of more secure, higher performance, and more cost-effective microsystems, associated software technologies, advanced mobile information technology and prototype experimental applications critical to defense operations. The project is comprised of six primary components - - Networking, Responsive Computing Architectures, Network Embedded Technology, Autonomous Systems Control and Augmented Cognition and Mixed Initiative Control of Automa-Teams.

(U) Program Accomplishments/Planned Programs:

	FY 2002	FY 2003	FY 2004	FY 2005
Networking	33.685	6.100	0.000	0.000

(U) The Networking programs are developing new paradigms in networking technologies to meet future defense and national security needs. The objective of the overall effort is to create highly robust and rapidly configurable networking capabilities essential for both secure national infrastructure and ad-hoc military networks through key innovations in software and hardware technologies. The results will be applicable to wired, wireless and mixed networks. The Networking component is comprised of Network Modeling and Simulation, Active Networks and Ultra High-Performance Networking.

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- The Network Modeling and Simulations program will develop tools to address the challenge of predicting the end-to-end and internal behavior of complex networks over a broad range of time scales, network sizes and composition. New models and simulators will enable reliable and rapid planning, design, analysis and configuration of military and emergency networks with minimal manual intervention. This program is funded under project ST-31 in FY 2003.

- The Active Networks program investigates the use of smart packet processing to enable new strategies in rapid network service introduction and enhancement. Active network-based authentication mechanisms will enable highly dynamic access control not possible with today's IP infrastructure.

- The Ultra High-Performance Networking program is advancing transparent all-optical networking and gigabit wireless techniques to dramatically enhance bandwidths available to end-applications. Gigabit end-speeds are essential for a multitude of defense applications involving distributed processing of sensor outputs. All-optical self-healing architectures are also being developed as a part of a concerted effort to create high-confidence networking infrastructures. New paradigms in wireless link techniques are also being explored to make possible robust networking in complex, harsh environments.

(U) Program Plans:

– Network Modeling and Simulation.
  -- Implement a scalable, measurement driven packet level parallel simulation achieving high-level architecture compliance, and 10-fold increase in speed over conventional sequential simulation.
  -- Develop mathematical models of end-end and internal network performance.
  -- Demonstrate prediction in DoD networks with fifty nodes.

– Active Networks.
  -- Develop and demonstrate: 1) Intrusion Detection and Response (IDR) prototype; 2) Active Network Operating System focused on policy-free security architecture and availability; and 3) the capability to operate within a mobile computing environment.
  -- Develop active network techniques for distributed network management, resource control, and distributed network service deployment, configuration, and management.

– Ultra High-Performance Networking.
  -- Demonstrate correlation of multi-gigabit per second transfer of radar signal streams from multiple sources.

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-- Demonstrate 16-32 video blanket media streams and client side browsers for display of these streams.
-- Design precision (1cm) network based geo-location system scalable to 100 nodes in an indoor setting.
-- Demonstrate hybrid optical/radio frequency self-healing link with proactive switching at 600 Mbps.

	FY 2002	FY 2003	FY 2004	FY 2005
Responsive Computing Architectures	27.756	59.276	55.712	47.566

(U) The Responsive Computing Architectures component is bringing needed flexibility to DoD systems. It is developing integrated computing subsystems that will respond in real-time to dramatic changes in mission application requirements and operating constraints based on the mission-of-the-day. The current projects are focused on energy/power management, quality of service, and algorithm/application computing diversity and scalable computing efficiency. This technology has direct and significant impact for military systems such as the Land Warrior/Objective Force, ground and airborne autonomous devices, distributed sensors, space sensors, and intelligence collection ground systems. The Responsive Computing Architecture component is comprised of Power Aware Computing and Communications, High Productivity Computing Systems, Thermodynamics of Randomized Computing and Network-Centric Infrastructure for Command, Control and Intelligence.

- The Power Aware Computing and Communications (PAC/C) program is developing an integrated software/hardware power management technology suite comprised of novel techniques that may be applied at all levels of a system from the chip to the system level. Embedded military computing systems such as future Land Warrior systems, autonomous devices, distributed sensors, and space sensors have extreme dynamic computational and energy requirements. PAC/C will enable embedded computing systems to reduce energy requirements by ten to one hundred-fold for energy constrained military applications ranging from hand-held computing devices to unmanned aerial vehicles.

- The High Productivity Computing Systems (HPCS) program will provide DoD with significant technology and capability advancements for the national security and industrial user communities by filling a high-end tera to petascale computing gap between today's late 1980's based technology High Performance Computing systems and the promise of quantum computing. This program is targeting high end computing, medium to long term, national security missions where U.S. superiority and security is threatened, according to two recent DoD studies. The proposed technology development plan is part of a three-phase program that will extend up to the end of this decade. The three phases are concept study, research and development, and full-scale development. HPCS will address a number of critical technology barriers over the next decade: (1) processor/bandwidth performance efficiency; (2) software availability/reliability of large

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scale computing systems; (3) integral hardware, software, application robustness; (4) intrusion resistance; (5) run-time software brittleness; (6) time-to-solution; and (7) cost of developing, operating, and maintaining DoD national security applications. As an example, performance (efficiency) for critical national security applications will be improved by 10-to-40 fold. Early identification of high-end computing application computing requirements, metrics, and performance prediction tools will be used throughout the program to assess both technical and schedule progress.

- The Thermodynamics of Randomized Computing program is a revolutionary approach to energy reduction based on the fact that randomized algorithms, because of their associated error probability, allow computing with greater uncertainty or (thermodynamic entropy than corresponding deterministic algorithms) and hence consume less energy. This program will provide an early proof-of-concept of the proposed novel idea from an energy perspective.

- The Network-Centric Infrastructure for Command, Control and Intelligence program is developing technologies to automatically create virtual work centers, called "habitats," that can bring together the right combination of people, computer systems, robots, and data to accomplish a specific set of tasks. These habitats can be dynamically reconfigured because they are "aware" of the interrelated combat conditions and the context of the environment. New technologies will be developed to allow the warfighter, at any level of command, to rapidly assemble a habitat that addresses the needs of a specific task e.g., geographic situation awareness, or command interfacing with coalitions. This program moves to ST-32 in FY 2003.

(U) Program Plans:

– Power Aware Computing and Communications.
  -- Demonstrate 10X power/energy aware reduction techniques across five power aware levels: 1) mission, 2) subsystem/algorithm, 3) software/compilation, 4) operating systems, 5) architecture/devices into the power aware simulator library.
  -- Conduct preliminary PAC/C energy simulation/modeling framework concept demonstration.
  -- Provide a beta release of the PAC/C energy aware simulator and modeling framework for the PAC/C subscale developers to evaluate.
  -- Finalize selection of the power aware technologies to be incorporated and demonstrated for each of the planned power aware subscale demonstration projects which include the following application areas: distributed sensors, space processing, Land Warrior/Objective Force, and communications.
  -- Continue the development of the final subscale demonstration projects and provide interim and final demonstrations.

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- High Productivity Computing Systems.
  - -- Perform an industry concept and critical technology assessment review for viable HPCS systems for potential implementation in the (2007 - 2009) timeframe.
  - -- Release alpha "value-based" productivity metrics and benchmarks to guide future program research and development activities.
  - -- Address large system brittleness by exploring hardware and software reliability/fault tolerance capabilities, active application software bug tolerance, and intrusion identification and resistance.
  - -- Explore balanced "productive" system architectures balancing processors, memory, interconnects, software, and programming environments.
  - -- Downselect viable system solutions and critical technologies to be prototyped; demonstrated and evaluated prior to full-scale implementation.

- Thermodynamics of Randomized Computing.
  - -- Establish the feasibility of using randomized algorithms to save energy via entropy management.
  - -- Define the computing model and demonstrate the thermodynamic behavior of randomized algorithms.
  - -- Implement in silicon the critical concepts of randomized computing.

- Network-Centric Infrastructure for Command, Control and Intelligence.
  - -- Develop Joint Service experimental plans.
  - -- Conduct studies to assess the ability of emerging COTS infrastructure technologies to support habitat construction, evolution, and interaction.

	FY 2002	FY 2003	FY 2004	FY 2005
Network Embedded Technology	24.215	33.187	15.335	0.000

(U) The Network Embedded Technology component will develop software technology to build distributed, real-time, and embedded applications, ranging from tens of computing nodes to over a million. Each program is driven by carefully selected Open Experimental Platforms to facilitate the continuous evaluation of progress and end-user influence. By using major theoretical breakthroughs during the past decade in hybrid systems, statistical physics, finite-size scaling, generative programming, and distributed control, the programs have solid foundation to

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achieve the ultimate goal of revolutionizing how software-intensive embedded platforms are built for the DoD. The Network Embedded Technology component is comprised of Networked Embedded Systems Technology and Program Composition for Embedded Systems.

- The Networked Embedded Systems Technology (NEST) program provides robust coordination and synthesis services subject to extreme timing, power, and resource constraints for networked embedded systems. The coming wave of microelectromechanical systems offer novel solutions for fine-grain distributed estimation and control applications. These applications contain at least 100,000 simple computing nodes. NEST is providing a reusable code-base, tools, and reference applications to dramatically simplify the software development task in a wide range of future weapon systems. If not done, application developers will need to constantly reinvent theoretically involved and computationally complex solutions for embedded subsystem coordination and synthesis, which cannot provide guarantees for predictable behavior of large-scale networked systems.

- The Programmable Composition of Embedded Software (PCES) program is developing technology to support faster, more reliable development of distributed embedded software for intelligent systems. This technology will enable programmers to safely and productively integrate so-called "cross-cutting" aspects, such as concurrency, synchronization, security, and memory management; along with the core functionality that implements intelligent software interaction with a diverse suite of sensors and actuators in real time. The reusable code-base, tools and reference applications being delivered by PCES leverage human effort to rapidly produce higher-quality, more adaptable software. PCES technologies are assuring that the resulting software achieves required properties and can enable the production of the next generation of high-confidence military systems that depend fundamentally on robust and efficient software operation.

(U) Program Plans:

– Network Embedded Systems Technology.
  -- Design deterministic and probabilistic methods for self-stabilizing protocols for lightweight coordination services such as global clock synchronization, sensor localization, etc.
  -- Conduct experimental and theoretical investigations on *phase-transition* effects (i.e., the dramatic changes from being easy to becoming intractable, in problems that involve the simultaneous satisfaction of multiple constraints).
  -- Investigate design approaches for the customization of coordination-services to specific applications.
  -- Develop formal modeling and verification techniques for coordination-services and for integrating them.
  -- Develop low-cost, Open Experimental Platforms for network embedded software technology.
  -- Conduct baseline demonstrations of NEST technology in a variety of environmental monitoring and tracking applications.

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-- Demonstrate real-time synthesis of schedules (e.g., for actuator firing sequences) and services (e.g., for localization, route planning) using phase transition-aware constraint solvers.
-- Develop customizable and adaptable solutions for coordination-services for network embedded software technology applications.
-- Develop tools for the automatic composition and verification of application specific coordination service packages.
-- Demonstrate the synthesis of an optimized coordination service package on the experimental platform.
-- Demonstrate the application design process and evaluate performance of a deployed thousand node sensor system capable of self-initialization, detecting, tracking and assisting in the pursuit of smart evaders.

– Program Composition for Embedded Software (PCES).
-- Develop scalable techniques for incremental formal validation and optimization of embedded software.
-- Develop language representation and compiler techniques for aspect-oriented programming of fine-grained and coarse-grained aspect-oriented programming of embedded systems.
-- Develop software analysis and composition tools that can reason about the complex interactions and tradeoffs among cross-cutting systemic aspects to enable safe code composition and manipulation that avoid multi-aspect interference.
-- Develop suites of reusable aspect software that implement cross-cutting systemic properties and mechanisms in a form suitable for composition by the automated analysis and composition tools.
-- Develop open standards-based model-driven tools and representations for generating, optimizing, and configuring component-oriented embedded system middleware and applications during various binding times, ranging from compile-time to run-time.
-- Develop quality-of-service enabled distributed services for persistence, fault tolerance, scheduling, and multi-media sensor data transmission.
-- Develop catalogs of patterns and pattern languages that formalize the successful techniques and constraints associated with developing and validating aspect-oriented embedded systems middleware and applications.
-- Develop open experimentation platforms that PCES technology developers and DoD system integrators can use to prototype and systematically evaluate PCES technology capabilities to prosecute time-critical targets in operational avionics and unmanned air vehicle systems.
-- Demonstrate control services for multi-media sensor data, pair-wise interacting aspects, transformation strategies, and program composition services for coordinated operations between manned/unmanned air vehicles and command and control centers.
-- Develop interacting aspects, transformation strategies, and program composition services for coordinated operations between manned/unmanned air vehicles and command and control centers.

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	FY 2002	FY 2003	FY 2004	FY 2005
Autonomous Systems Control	24.237	6.001	0.000	0.000

(U) The Autonomous Systems Control component will develop the tools necessary to deploy, control and coordinate the full spectrum of autonomous system resources effectively and efficiently in order to ensure mission success. DoD systems are rapidly becoming hybrids, incorporating both humans and autonomous system components such as robots and software agents; developing the software to achieve that integration is the subject of this component. The Autonomous Systems Control component is comprised of Autonomous Negotiation Teams and Autonomous Software for Learning Perception & Control.

- The Autonomous Negotiation Teams program is developing the software technology to resolve time-critical constraints in logistics and mission planning. The resource management problem is being solved via the interaction of lightweight, mobile software components using a bottom-up organization approach and negotiation as techniques for resolving ambiguities and conflicts. The technology enables designers to build systems that operate effectively in highly decentralized environments, making maximum use of local information, providing solutions that are both good enough, and soon enough.

- The Autonomous Software for Learning Perception and Control program will program autonomous mobile robots to independently perform a variety of military tasks in a diverse spectrum of complex, dynamic environments. The goal is to achieve validated performance at near-human levels in a full range of real-world environments for perception-based autonomous vehicle driving/navigation and effective interaction of robots with humans. This program is pursuing several alternative approaches to augment pre-programmed activities and responses with powerful learning-derived competencies for perception and control analogous to those of biological systems. In other words, this software will enable autonomous systems to modify their behavior in response to real-world situations or barriers. Integrated perception, including fusion of data from multiple sensor and multiple processing modalities of the same data will reduce operator intervention and achieve semi-autonomous operation. The result will be highly capable robots that can learn new tasks and adapt quickly to new environments with minimal programming effort, with numerous applications in the battle space of the future. This program is funded under project ST-33 in FY 2003.

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(U) Program Plans:

- Autonomous Negotiation Teams.
  - -- Demonstrate ability to identify autonomous negotiating teams needed for cooperative flight scheduling and maintenance planning.
  - -- Demonstrate prototype implementation and evaluation of negotiation in real-time mission planning for Harrier aircraft mission planning and maintenance operations.
  - -- Demonstrate ability for hierarchical coalition formation in real-time and avoidance of conflict by changing plans.
  - -- Demonstrate an integrated utility for the selection of negotiation strategies to meet goals of convergence, optimality, timeliness and stability in changing environments.
  - -- Demonstrate dynamic re-synthesis of the application under time limit using distributed constraint solvers.

- Autonomous Software for Learning Perception and Control.
  - -- Demonstrate behavior scalability and reuse; learning compatible knowledge representations; and task-based, sensor data exploitation.
  - -- Identify metrics for evaluation and associated evaluation methodologies.

	FY 2002	FY 2003	FY 2004	FY 2005
Augmented Cognition	12.771	0.000	0.000	0.000

(U) The Augmented Cognition component focuses on developing technologies to augment the warfighter's cognitive capacity and capabilities. This is a new research area designed to significantly expand human capability by augmenting human cognition and performance in the way that weapons, vehicles and sensors significantly extend human capabilities. The hypothesis of this emerging field is that the impressive progress in neural science, computation and miniaturization can now be leveraged to enable new concepts of warfare. The Augmented Cognition component contains two efforts: Augmented Cognition and the Perceptual Processing Display program.

- The Augmented Cognition (AugCog) program will develop the means to measure a subject's cognitive state in real time and then manipulate that state in order to greatly improve the performance of various functions in the human machine interface paradigm. The goal of the Augmented Cognition program is to develop the technology to integrate new digital devices that support memory, perception, and thinking, and link that support with the user's context state information to directly improve the overall cognitive performance of the warfighter in complex and operationally stressful conditions. The program will culminate in the development of a closed-loop human-

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computer interaction capability with the computer able to anticipate, predict, and augment the performance of the user. This program is funded under project ST-31 in FY 2003.

- The Perceptual Processing Display program studied advances in neuroscience and perceptual processing technologies to develop new and redesigned devices that deliver information to the human perceptual system. Technologies were explored to simplify relevant and eliminate irrelevant information that will lead to improved perception, comprehension, memory, inference, and decision-making.

(U) Program Plans:

– Augmented Cognition.
  -- Develop and evaluate non-invasive, real-time, cognitive state detection technology for measuring the cognitive processing state of the user.
  -- Develop new Functional Optical Imaging sensor system technical approaches based on Near Infra-Red and validate the technologies as a means to monitor prefrontal cortex activity.
  -- Establish and implement cognitive relaxed computer dialog architecture to support the warfighter in natural language interface with the computer.

– Perceptual Processing Displays.
  -- Determined optimal methodologies and technologies to expand and exploit the perceptual-cognitive processing bandwidth.
  -- Evaluated technologies to enhance the color, luminance range, sharpness, contrast, and motion sensitivity to match human capabilities not exploited by conventional display systems.

	FY 2002	FY 2003	FY 2004	FY 2005
Mixed Initiative Control of Automa-Teams (MICA)	10.526	16.678	0.000	0.000

(U) The Mixed Initiative Control of Automa-teams (MICA) program is developing algorithms, software, modeling and simulation capabilities to perform multi-level planning, assessment and control of distributed, autonomous combat forces. MICA will provide a commander the operational and mission planning tools to select optimal team composition, to perform dynamic tasking and re-tasking of teams, and to generate cooperative routes for autonomous unmanned air vehicles in stressful operational missions, especially suppression of enemy air defenses. Mixed

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initiative control will develop collaborative strategies and tactics for these teams under the supervision of a single human operator, with adjustable autonomy determining the degree of human authority desired or required during task execution. Through the exploitation of control science metrics for stability, performance and robustness, these teams of cooperative, autonomous vehicles such as unmanned combat air vehicles will accommodate uncertainty in both the operating environment and feedback information, as well as address the presence of an intelligent adversary and fixed/mobile threats in the battlespace. An open experimental platform will be employed to evaluate these hierarchical battle management and control methodologies with humans-in-the-loop, initially in a simulation and subsequently in a hardware demonstration. In FY 2004 and beyond, this program will be funded in PE 0602702E, Project TT-13.

(U) Program Plans:

- Develop algorithms and software to assign autonomous combat vehicles to task-oriented teams and to assign mission-derived subtasks and generate events schedules and collaborative routes to each combat vehicle in a team.
- Apply and refine algorithms and software supporting dialog between human commanders/operators and semi-autonomous entities to communicate recommended courses of action, appropriate feedback information, and decision tuning parameters.
- Deploy a second phase open experimental simulation environment, driven by suppression of fixed and mobile air defense elements, time sensitive targets, and incorporating multiple UAV teams and multiple command levels.

	FY 2002	FY 2003	FY 2004	FY 2005
Data Intensive Systems	2.311	0.000	0.000	0.000

(U) The Data Intensive Systems component developed new hardware, software, and algorithmic approaches to computer memory organization and access that eliminated severe bottlenecks in present designs. Many defense applications such as dynamic, sensor-based processing, battlefield data-processing integration, and high-speed cryptographic analysis are data-starved, that is to say, the processor is so fast that it has to wait for memory to be accessed from RAM between operations thus slowing down the computation. This program developed innovative data access techniques to solve this problem and enable new military capabilities with high rate sensor data streams and irregular data base memory access requirements.

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(U) Program Plans:
- Incorporated additional floating point capability to a PIM chip.
- Demonstrated PIM technology in place of a conventional memory module to act as an intelligent memory module capable of performing data intensive computing.

	FY 2002	FY 2003	FY 2004	FY 2005
System Engineering for Miniature Devices	2.600	0.000	0.000	0.000

(U) The Systems Engineering for Miniature Devices research project focused on the integration of existing/emerging technologies in the areas of mobility, power, sensing, actuation, communication, and computation, with a special focus on the software issues involved in controlling and programming these devices.

(U) Program Plans:
- Conducted system engineering for mini devices effort.

	FY 2002	FY 2003	FY 2004	FY 2005
Secure and Dependable Software	1.000	0.000	0.000	0.000

(U) The Secure and Dependable Software Program developed technologies to enable production of secure and dependable software for Military's mission-critical applications. It addressed the need for cost-effective technological tools to monitor, assess, analyze and predict threats and risks.

(U) Program Plans:
- Developed specific tasks for mobile agents in forensic analysis and risk assessment.
- Mapped the strategies and behaviors of mobile agents for gathering information, investigating events and activities and assessing data for compliance with known standards and controls.

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(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Information Assurance and Survivability ST-24	65.204	44.892	44.459	44.898	69.474	73.283	87.855	87.768

(U) Mission Description:

(U) This project is developing the technology required to make emerging information system capabilities (such as wireless and mobile code/mobile systems) inherently secure, and to protect DoD's mission-critical systems against attack upon or through the supporting information infrastructure. These technologies will enable our critical systems to provide continuous correct operation even when they are attacked, and will lead to generations of stronger protection, higher performance, and more cost-effective security and survivability solutions scalable to several thousand sites. Technologies developed under this project will be exploited by all the projects within this program element, and by the Command and Control Information Systems (Project CCC-01, PE 0603760E), Information Integration Systems (Project CCC-02, PE 0603760E), and other programs that satisfy defense requirements for secure and survivable systems.

(U) Program Accomplishments/Planned Programs:

	FY 2002	FY 2003	FY 2004	FY 2005
Fault Tolerant Networks	34.622	15.235	3.000	0.000

(U) The Fault Tolerant Networks (FTN) program will develop technologies to provide continuous and correct network operation even when attacks are successful. These technologies will reduce the amount of damage sustained during an attack, allowing networks to maintain an acceptable, minimum level of functionality. Technologies for strengthening networks will be developed by introducing fault tolerance capabilities against possible attacks at the network level, emphasizing integrity and availability; and technologies for mitigating potential vulnerabilities associated with denial of service attacks. The most promising of these technologies will be tested in operationally relevant experiments with U.S. warfighters in DARPA's Partners in Experimentation program, which is also budgeted in this project.

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(U) Program Plans:

- Demonstrate Source Path Isolation Engine experimentation using Collaborative Advance Interagency Research Network and commercial-off-the-shelf intrusion detection systems to show the trace of an attack back to its ingress point soon after attack.
- Develop capability to provide detection of denial of service attacks on the Quality of Service data flow and to isolate the attacking packet streams using the concept of congestion pricing in resource reservation, the security of resource reservation will be enhanced against insider router attacks.
- Demonstrate a scalable architecture and localized optimization algorithms for constructing a dynamic, topologically sensitive root context for any network topology, thus, removing the dependence of a single, fixed root content for the domain name server.
- Explore traffic modeling techniques for traffic analysis and for countermeasures to denial of service attacks in wired and wireless networks; develop a tool set that provides survivable real-time communication services.
- Design new, efficient algorithms for detecting attacks and faults in optical networks, including models and algorithms for cost-based approaches to reserving routes and bandwidth in anticipation of attacks and faults.
- Develop onion routing system, a virtual overlay network for resilience to traffic analysis in operational field use.
- Develop a distributed, scalable, reliable, and cost-effective architecture for an active network router that schedules node resources and dynamically reconfigures itself in response to failures.
- Design and develop modifications to Source-initiated Ad-hoc Routing Algorithm to incorporate techniques for intrusion-resistant mechanisms for Flow-based Route Access Control, multi-path routing, and flow monitoring algorithms.
- Develop mobile distributed firewall architectures to allow rapid deployment of mobile networks with full enclave protection.
- Provide public key infrastructure support for rapid revocation of individuals, to include terminal exclusion and network reconfiguration.

	FY 2002	FY 2003	FY 2004	FY 2005
Dynamic Coalitions	9.898	10.618	2.009	2.000

(U) The Dynamic Coalitions program is developing technologies to support the secure creation of dynamic coalitions including the necessary technologies for policy management, group communications, supporting security infrastructure services, data sharing, and joint collaboration spaces. These areas are critical for future warfighting scenarios as outlined by Joint Vision 2020, which states that future military operations will

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be increasingly conducted jointly, both with multiple branches of the U.S. Armed Forces and with allied and coalition forces, requiring increased levels of interoperability. Further, this effort will build upon recent advancements in wireless networking technologies by investigating technologies to migrate coalition information assurance tools from servers to gateway radios thus placing the functionality directly at the interface, and localizing coalition policy to gateways. The most promising technologies developed under this program will be tested in operationally relevant experiments with U.S. warfighters in DARPA's Partners in Experimentation program, which is also budgeted in this project.

(U) Program Plans:

- Develop extensions to team-based access controls addressing dynamic coalition membership and coalition missions, access to coalition resources at the task level, and modeling the use of self-limiting resource permissions that evolve with the state of mission-oriented tasks.
- Develop algorithms that will remove dynamic group management bottlenecks by replacement of public-key techniques with much faster secret-key techniques, insertion of computational shortcuts, and potentially, the replacement of cryptography with secret-sharing techniques (for additional performance gains).
- Develop and demonstrate several intra-domain group key management approaches for mobile subscribers, built around a decentralized, hierarchical architecture: one approach based on current Internet Engineering Task Force (IETF) IPSec multicast key management proposal; a second using same approach modulated by a hysteresis interval for environments with unreliable connectivity; a third using explicit handoff of security associations among key distributors; and finally, an approach using periodic re-keying.
- Develop a general framework for hierarchical access control, decoupling rights authorization from information and service access, resulting in enhanced coalition scalability.
- Design, develop and integrate new certificate cache architectures with secure group communication system.
- Develop a cryptographic hardware accelerator to speed up cryptographic computations for devices used in coalition networks.
- Demonstrate integrated facilities for transitive delegation, with support for capacity sandboxing, reverse sandboxing, and object caching.
- Develop and demonstrate intra-domain group key management protocols extended to handle mobile key distributors within mobile networks.
- Develop a modular architecture and robust key agreement within a dynamic coalition, including reconfigurability and evaluation.

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	FY 2002	FY 2003	FY 2004	FY 2005
Cyber Panel	10.745	4.155	1.000	0.000

(U) The Cyber Panel Program is developing capabilities to help defend mission-critical information systems by monitoring them for signs of cyber attack, and allowing operators to manage the operation of system security and survivability features to avert or counter developing attack situations. Intrusion assessment technologies are being developed to detect security threats through correlation and analysis of observed/reported activities. Autonomic response capabilities are being developed to react in milliseconds to block or withstand many classes of known and unknown attacks. Monitoring and response components are being developed that allow warfighters to observe the performance, health and threat state of mission critical information systems, project the likely impact of reported cyber attacks on system operation, assess possible defensive actions, and carry them out. The Cyber Panel program will help reduce the vulnerability of military systems to strategic cyber attacks by creating technologies that enable human-directed command and control over cyber resources, operationally relevant cyber situational understanding, mission impact assessment, and defensive response evaluation and execution. The most promising of these technologies will be tested in operationally relevant experiments with U.S. warfighters in DARPA's Partners in Experimentation program, which is also budgeted in this project.

(U) Program Plans:

- Investigate methods for augmenting passive intrusion detection sensors with capabilities to actively probe for additional attack information.
- Explore techniques for improving the effectiveness of auto-response defenses with limited intelligence about attack models.
- Experiment to determine the usability of general-purpose anomaly detection algorithms to monitor a large, complex military software system.
- Combine selected Cyber Panel technologies into an integrated demonstration prototype incorporating cyber attack detection, correlation, assessment, and response capabilities.

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Partners in Experimentation	9.939	4.544	6.044	0.000

(U) The Partners in Experimentation program will conduct security technology experimentation with operational military and coalition partners. Operational experimentation will provide valuable feedback to the security technology research and development process which will demonstrate to operational personnel the benefits of advanced technology, and accelerate technology transition.

(U) Program plans:

- Convert intrusion assessment algorithms into data reduction tools for military computer intrusion detection analysts.
- Demonstrate situational awareness and interactive "big-board" control of broadly distributed security technologies, including scalable host based defenses, in military operational environment.
- Demonstrate large-scale hardened client technology and policy implementation in military operational environment.
- Evaluate performance and scalability of lab proven anomaly detection techniques for intrusion detection in real world high volume environments.

	FY 2002	FY 2003	FY 2004	FY 2005
Composable High Assurance Trusted Systems (CHATS)	0.000	4.340	4.017	0.000

(U) The Composable High Assurance Trusted Systems (CHATS) program is developing the tools and technology that enable the core network services to be protected from the introduction and execution of malicious code or other attack techniques and methods. These tools and technologies will provide the high assurance, trusted operating systems context/basis to host the planned security services needed to achieve comprehensive-secure, highly distributed, mission-critical information systems for the DoD. This project will fundamentally change the existing approach to development and acquisition of high assurance trusted operating systems technology. These trusted operating system capabilities will be developed by engaging the open-source community in security functionality for existing open-source operating systems. Additionally, DARPA will engage the open-source community in a consortium-based approach to create a "neutral", secure operating system architecture framework. This security architecture framework will then be used to develop techniques for composing operating system capabilities to support both servers

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and clients in the increasing network-centric communications fabric of the DoD. These technologies are critical for defensive information warfare capabilities and are needed to ensure that DoD systems of the future are protected from imminent attack. This program was originally funded in this PE under Project ST-11 in FY 2002 and prior.

(U) Program Plans:

- Implement prototype adaptations of the preferred applications and services as indicated by the protection profiles.
- Implement the composable high assurance trusted system and the adapted applications and services on candidate representative DoD mission critical system server fabric.
- Investigate alternative approaches for extending the composable high assurance technology to the network client fabric.
- Develop protection profiles for the best candidate high assurance client side trusted systems.
- Implement the best of the lifecycle support alternatives.
- Investigate the alternative technology transfer options that provide the best long term persistence and continuity for the CHATS technology and tools.

	FY 2002	FY 2003	FY 2004	FY 2005
Next Generation Optical Networks	0.000	2.000	8.671	14.486

(U) The Next Generation Optical Networks program will revolutionize the operation, performance, security, and survivability of the United States' critical inter-networking system by leveraging technology developed in DARPA photonics component and secure networking programs. These goals will be accomplished through a transformation in fundamental networking concepts that form the foundation upon which future internetworking hardware, architecture, protocols and applications will be built. Key technical enablers that will be developed in this thrust include: the elimination of data flow bottlenecks through the creation of optical network hardware that minimizes the occurrence of optical-to-electrical-to-optical conversions, network management tools that guarantee optimization of high density optical channels such as those provided by wavelength division multiplexing, the creation of a new class of protocols that permit the cross-layer communications needed to support quality-of-service requirements of high priority national defense applications, and novel concepts in intelligent and cognitive switched based networks. Integration of terrestrial fiber optic lines with free-space optical and RF wireless transport systems, and establishment of a CONUS wide testbed with mobile overseas nodes will enable development, experimentation, and validation of new hardware, software, and network

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architecture concepts. This effort will deliver the high-performance internetworking capabilities needed for development of applications such as distributed and network based command and control, intelligence analysis, predictive logistics management, simulation and scenario enhanced decision-making support for real-time combat operations, and assured operation of critical U.S. networking functions when faced with severe physical layer attack. These network-based functions will support the real-time, fast-reaction operations of senior leadership, major commands and field units. In addition, the insertion of optical networking technologies within highly integrated weapon system platforms, such as tactical aircraft, will be investigated as possible upgrades to current platforms and future platform designs.

(U) Program Plans:

- All-optical hardware design and fabrication, regeneration and optical wavelength switching enabled.
- Network data flow/bottleneck analysis, 10 Gb/s to end user.
- Switch architecture design for zero apparent jitter real-time applications.
- National testbed hardware specification, local area to wide area network integration, with data-format independence.
- Protocol development for physical layer-to-application layer connectivity.
- Analyze optical technologies for use in highly integrated weapon platforms to determine suitability for upgrades and future designs.

	FY 2002	FY 2003	FY 2004	FY 2005
Malicious Code Analysis Program	0.000	2.000	9.859	14.807

(U) The goal of the malicious code analysis program is to develop dynamic quarantine defenses for U.S. military networks against large-scale malicious code attacks such as computer-based worms. The ever-growing sophistication of the malicious code threat has surpassed the ability of commercial industry to address this problem. As the U.S. military pushes forward with network-centric warfare, terrorists and other nation-states are likely to develop and employ malicious code to impede our ability to fight efficiently and effectively. This program will develop the capability to automatically detect and respond to worm-based attacks against military networks, provide advanced warning to other DoD enterprise networks, study and determine the worm's propagation and epidemiology, and provide off-line rapid response forensic analysis of malicious code to identify its capabilities, modalities, and future behavior. Technical approaches include the development of a hybrid/hierarchical/distributed architecture for notifying cooperating nodes of a worm attack, automatic and dynamic quarantine response, generalizable signatures for detection and forensics

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analysis of malicious code that will employ static and dynamic code analysis for program understanding. This effort represents the next step in the continuum of information assurance programs that DARPA has pioneered and pursued.

(U) Program Plans:
- Create architecture for distributing worm alerts and blocking signatures over large-scale networks faster than worm speed.
- Develop automatic detection and quarantine mechanisms.
- Provide real-time and off-line analysis capabilities.
- Develop network appliance and host-based detection/response network interface devices.
- Verify integrated system capabilities.

	FY 2002	FY 2003	FY 2004	FY 2005
Trustworthy Systems	0.000	2.000	9.859	13.605

(U) Sophisticated computing capabilities like those available in current desktop workstation and server systems are moving to mobile wireless embedded systems that communicate over low bandwidth self-organizing tactical networks often with low-powered devices. Concomitant with the advanced computing capability will be security and other trustworthiness challenges in the systems on which the future U.S. military will be heavily dependent during battle. The 21st century transformation of the U.S. military will be more dependent on information technology for C^4ISR and combat functions than perhaps any other aspect of the military. To a large extent, future combat systems will be more dependent on information than armor to accomplish missions successfully. The Department's vision for the future includes near-perfect knowledge of the battlespace and the ability to fight wars with information technology that enables remote C^4ISR operations. The goal of the Trustworthy Systems program is to develop the means to measure and enable trustworthiness in embedded tactical systems and the capability to provide undeniable computer and Internet access into and out of currently denied cyberspace territories. This program will develop mechanisms for software-enabled monitoring, measurement, and control employing design-for-trustworthiness concepts. Key capabilities developed under this program will be the ability to dynamically measure trust based on prior and current system behavior and mission context, optimize a system for a particular trustworthiness attribute such as security, reliability, or performance, and provide real-time monitoring, autonomic and emergency response for when systems begin to behave in a non-trustworthy manner. By leveraging technologies developed in Cyber Panel and High Confidence Systems programs, coupled with network attack responses and embedded systems development, this capability will integrate local attack correlation

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sensors, provide attack visualization tools for local and regional responders, provide continuous update of mission health/impact assessment, and generate course of action auto-planning and execution.

(U) Program Plans:

- Develop fundamental principles and approaches to design for trustworthiness.
- Identify dynamic indicators of system unreliability & insecurity.
- Develop approaches for real-time software monitoring.
- Identify metrics for trustworthiness.
- Develop approaches for empirical measurement of trustworthiness.
- Develop models for software-enabled control.
- Develop methods for undeniable cyber access out of denied territories.
- Explore processors capable of fully encrypting the entire state of computation at each step.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Asymmetric Threat ST-28	56.775	77.034	79.114	80.878	91.284	107.190	119.580	119.513

(U) Mission Description:

(U) The most serious threat to our national security today is *asymmetric* in nature. It is not the threat of a conventional, force-on-force engagement by an opposing military, but instead, the threat of an unconventional yet highly lethal attack by a loosely organized group of transnational terrorists or other factions seeking to influence U.S. policy. This new threat brings new technological challenges to the U.S. The U.S. will need to develop technology to detect, identify, classify, and track small, shadowy, hard to define and identify, and loosely organized terrorist groups as they plan adverse actions against the U.S. This new threat will have a smaller mass, exhibit fewer observables, and yet will be more lethal in consequence. Sparse activity that was once too insignificant to notice will need to be detected, correlated, and understood. This can only be achieved by developing a new level of automation to detect, correlate, and understand all of the observable evidence exhibited by these sparse events. Specific needs include the capability to automatically recognize and identify humans at a distance in order to detect any enemy agent performing surveillance of a U.S. target; to automatically discover, extract, and link together sparse evidence of a group's intentions and activities from vast amounts of classified and unclassified information sources; to more precisely model the beliefs and organizational behavior of these small groups to better simulate and wargame our new opponents in this asymmetric world; and to provide more effective collaborative reasoning and decision aids to improve the speed and effectiveness of distributed teams of analysts and decision-makers in these dynamic situations.

(U) The goal of this project is to develop technological capabilities and a suite of tools to better detect and prevent attacks upon our critical DoD infrastructures. Ongoing programs in this project are Human Identification at a Distance (Human ID), Evidence Extraction and Link Discovery (EELD), Wargaming the Asymmetric Environment (WAE) and Bio-event Advanced Leading Indicator Technology (Bio-ALIRT, formerly referred to as Bio-Surveillance). These programs will provide capabilities to the Total Information Awareness (TIA) network, a program funded in project CCC-03. A suite of new or on-going programs are also funded including Genisys, Genisys Privacy Protection, Mis-Information Detection (MInDet), Activity Recognition and Monitoring (ARM), Future Markets Applied to Prediction (FutureMAP), Scalable Social Network Analysis Algorithms, Next Generation Face Recognition (NGFR), Rapid Analytical Wargaming (RAW), Deception, and Counter Suicide Bombers.

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(U) Program Accomplishments/Planned Programs:

	FY 2002	FY 2003	FY 2004	FY 2005
Human Identification at a Distance	16.710	11.120	4.325	0.000

(U) The Human Identification at a Distance (HumanID) program is developing automated multi-modal biometric technologies. These technologies will be used to detect, recognize and identify humans at a distance. Automated biometric recognition technologies will provide critical early warning support against terrorist, criminal, and other human-based threats. Obtaining this information can prevent or decrease the success rate of such attacks and provide more secure force protection of DoD operational facilities and installations. HumanID seeks to develop a variety of individual biometric identification technologies capable of identifying humans at great distances in DoD operational environments and for homeland defense. Once these individual technologies are developed, HumanID will develop methods for fusing these technologies into an advanced human identification system. This system will be capable of multi-modal fusion using different biometric techniques with a focus on body parts identification, face identification, and human kinematics. Biometric signatures will be acquired from various collection sensors including video, infrared and multi-spectral sensors. These sensors will be networked to allow for complete coverage of large facilities. The goal of this program is to identify humans as unique individuals (not necessarily by name) at a distance, at any time day of night, during all weather conditions, with non-cooperative subjects, possibly disguised and alone or in groups. These technologies will be tested and integrated into the Total Information Awareness (TIA) network funded in PE 0603760E, Project CCC-03.

(U) Program Plans:

- Designed and administered the Face Recognition Vendor Test 2002 and analyzed and evaluated results.
- Develop a multi-spectral infrared and visible face recognition system and plan to test and evaluate it in operational environments on a large number of subjects.
- Identify the limits of range, accuracy, and reliability on combinations of facial features, gait, and other key identification techniques and determine the critical factors that affect the performance of biometric components.
- Continue the development of the most promising biometric technologies based upon experimental evaluation performance.
- Develop methods and algorithms for fusing multi-modal biometric technologies and deriving biometric signatures.
- Incorporate additional sensors and biometrics into the pilot force protection system.

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- Evaluate and demonstrate the prototype advanced human identification system at force protection and homeland defense sites.
- Use the results of the Face Recognition Vendor Test 2002 to direct face recognition research and provide input to the design of the United States Border Entry/Exit System.
- Perform an operational evaluation of a long-range (25-150 feet) face recognition system developed under the HumanID Program.
- Develop and evaluate a low power millimeter wave radar system for wide field of view detection and narrow field of view gait classification.
- Characterize gait performance from video for human identification at a distance.
- Develop multi-modal HumanID technologies and extend the prototype advanced human identification system by adding two additional biometric modalities.
- Continue to develop biometric fusion algorithms to include up to five biometric components.
- Conduct multi-modal fusion experiments and performance evaluations and develop multi-model fusion algorithms for human identification.
- Demonstrate advanced human recognition capabilities in multiple force protection or homeland defense environments.
- Develop algorithms for locating and acquiring subjects out to 150 meters (500 ft) in range.
- Develop and demonstrate a human identification system that operates out to 150 meters (500 ft.) using visible imagery.
- Fuse face and gait recognition into a 24/7 human identification system.
- Perform an operational evaluation of a multi-modal human identification system.

	FY 2002	FY 2003	FY 2004	FY 2005
Next Generation Face Recognition (NGFR)	0.000	0.000	7.000	10.140

(U) Face recognition technology has matured over the last decade, with commercial systems recognizing faces from frontal still imagery (e.g., mug shots). These systems operate in structured scenarios where physical and environmental characteristics are known and controlled. Performance under these conditions has been documented in the Face Recognition Vendor Test (FRVT) 2000 and in the FRVT 2002 conducted in summer 2002. These evaluations document the advances in this technology. However, these evaluations have also identified performance shortfalls in critical operational scenarios, which include unstructured outdoor environments. The ability to operate in these operational scenarios is critical to military, force protection, intelligence and homeland defense applications. New techniques have recently emerged that have the

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potential to significantly improve face recognition capabilities in unstructured environments. These include three-dimensional imagery and processing techniques, expression analysis, use of temporal information inherent in video, and face recognition from infrared and multi-spectral imagery.

(U) The Next Generation Face Recognition (NGFR) program will leverage and expand upon efforts begun under the Human Identification at a Distance program and will initiate development of a new generation of facial based biometrics that can be successfully employed in a wide variety of unstructured military and intelligence scenarios. The critical components of this program are: 1) a systematic development and evaluation of new approaches to face recognition, 2) maturation of prototype systems at operational sites, 3) experimentation on databases of at least one million individuals, and 4) collection of a large database of facial imagery which includes the variations in facial imagery found in unstructured environments. The NGFR will produce face recognition systems that are robust to time differences between facial imagery (aging), variations in pose, illumination and expression. The required breakthroughs in face recognition will be a result of the coordinated synthesis of the four key components of the program. These technologies will be tested and integrated into the Total Information Awareness (TIA) network funded in PE 0603760E, Project CCC-03.

(U) Program Plans:
- Explore new face recognition technologies and approaches and use them to improve the accuracy of existing technologies.
- Incorporate advances resulting from this research into a variety of prototype systems to demonstrate their capability across varied operational scenarios.
- Develop Advanced Imaging Face Recognition Technologies – three-dimensional, infrared, and multi-spectral imaging technologies.
- Collect a comprehensive data set of facial imagery that is representative of faces in unstructured outdoor environments.
- Conduct large-scale experiments and evaluations using large image databases of over a million people.

	FY 2002	FY 2003	FY 2004	FY 2005
Evidence Extraction and Link Discovery	12.309	16.552	10.265	5.515

(U) The objective of the Evidence Extraction and Link Discovery (EELD) program is to develop a suite of technologies that will automatically extract evidence about relationships between people, organizations, places, and things from vast amounts of unstructured textual data (such as

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intelligence messages or news reports) leading to the discovery of additional relevant relationships and patterns of activity that correspond to unusual events, potential threats or planned attacks. These technologies would be employed to provide more accurate advance warnings of potential terrorist activities by known, or more important, unknown individuals or groups. They will allow for the identification of connected items of information from multiple sources and databases whose significance is not apparent until the connections are made.

(U) Recent advances in language understanding software will be exploited to provide a capability to automatically extract facts from textual messages, web pages, and other unstructured data sources at a performance level (90 percent accuracy) comparable to today's ability to extract entities (e.g., people, places, organizations). Search, representation, reasoning, and classification techniques will be developed to enable discovery of relevant information and evaluate it to detect likely threats. Pattern learning algorithms will be extended and scaled to enable learning and evaluation of patterns comprised of relationships among people, organizations, activities, and scenarios, with the ability to distinguish accurately between real activities of interest and explainable unusual events. These technologies will be tested and integrated into the Total Information Awareness (TIA) network. In summary, EELD develops technology not only for "connecting the dots" but also for deciding which dots to connect – starting with people, places, or organizations known or suspected to be suspicious based on intelligence reports, recognizing patterns of connections and activity corresponding to scenarios of concern between these people, places, and organizations, and learning patterns to discriminate as accurately as possible between real concerns and apparently similar but actually legitimate activities.

(U) Program Plans:

- Specify models and corresponding patterns of asymmetric threat scenarios.
- Develop and establish baseline performance for information extraction techniques for extracting geographical, organizational, and transactional relationships from text messages, news reports and web pages.
- Develop ability to discover relevant connections between entities of the same type.
- Develop ability to learn patterns corresponding to threat models comprising connections of single-type entities (e.g., people to people, or sets of related financial transaction) and to discriminate accurately between instances of these patterns representing suspicious activity and representing apparently similar but legitimate activities.
- Implement prototype demonstration of maturing EELD tools and techniques with DoD partners for potential transition opportunity of technologies for near-term support.
- Demonstrate integrated extraction capability for all relationship types from all source types, including rapid adaptability to new types of relationships and new data sources.

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- Develop ability to learn patterns comprising connections of multiple entity types with multiple types of connections and to discriminate accurately between instances of these patterns representing suspicious activity and representing apparently similar but legitimate activities.
- Conduct performance evaluation of all capabilities and model performance of combined capabilities.
- Develop ability to extract links and relationships from processed textual summary of information obtained from streaming (audio/video), imagery and sensor data.
- Develop adaptable relationship extraction capability for extracting facts from all textual sources.
- Develop the capability to recognize and to learn temporal patterns and to discriminate accurately between instances of these patterns representing suspicious activity and representing apparently similar but legitimate activities.
- Implement maturing EELD tools and algorithms in TIA exercises for transitioning into an operational environment via the TIA network.
- Integrate and evaluate EELD component technologies into the TIA network.

	FY 2002	FY 2003	FY 2004	FY 2005
Wargaming the Asymmetric Environment	14.836	18.604	8.221	0.000

(U) The Wargaming the Asymmetric Environment (WAE) program is developing and demonstrating threat specific tools to enable analysts and decision makers to better anticipate, predict, and intervene against terrorists and others who threaten U.S. and Allied interests with asymmetric and asynchronous capabilities. The technical challenges include 1) developing predictive methodologies and technologies that work within the complex and non-linear characteristics of today's asymmetric adversaries, 2) developing predictive technologies that will generalize from individuals to groups, from attack behavior to more subtle enabling behaviors/decisions that precede an attack, and 3) developing emulation (predictive sequences) technologies to allow analysts to test a projected adversary's actions and reactions to potential intervention strategies. WAE's approach to these technical challenges is to exploit a combination of behavioral prediction and computer-based reasoning techniques to automatically identify and model factors reflecting a specific groups "intent" and "points of influence" to support prediction and reasoning – at operationally relevant levels - about the future behavior of individuals and groups. This approach goes beyond today's analytical methods to analyze behaviors in the broader context of their political, psychological, and cultural environment. These predictive technologies will be tested and integrated into the Total Information Awareness (TIA) network.

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(U) Program Plans:

- Establish operational testbeds in conjunction with multiple transition partners (Joint Staff, DIA and CIA).
- Extend predictive model development to finer levels of details of tactic, target, location, timeframe, and severity characteristics.
- Develop predictive models for specific and existing Tier 0 and 1 individual and group adversaries.
- Generalize predictive models from a single adversary to multiple adversaries (asymmetric classes).
- Conduct generalization experiments to empirically define classes of asymmetric threats by common predictive factors.
- Continue to test and validate threat specific models and modeling techniques.
- Transition three predictive models to operational partners.
- Expand predictive modeling to Operations Other Than War (OOTW) context.
- Perform operational, real-time tests through the development and validation of predictive models.
- Perform predictive comparison between the current analytical models and the WAE modified analytical model.
- Extend predictive techniques to develop sequences of behaviors (emulation) for specific and classes of adversaries.
- Transition new and revised predictive models to operational partners.
- Integrate predictive technologies into an automated indication and warning system.
- Beta test automated indication and warning system in conjunction with operational partners (Joint Staff, DIA, and CIA).
- Develop automated tools to optimize the number and content of factors for each predictive model.
- Perform operational tests through the development and validation of emulation models.
- Develop end-to-end automated test environment.
- Develop and test automated, real-time detectors for each predictive models.
- Develop automated model development tools.
- Integrate into TIA network test bed.
- Transition models and predictive tools to operational partners.

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	FY 2002	FY 2003	FY 2004	FY 2005
Bio-ALIRT (Formerly Bio-Surveillance)	12.920	14.173	6.276	0.000

(U) The objective of the Bio-event Advanced Leading Indicator Technology program (Bio-ALIRT) is to develop the necessary information sources, technologies and prototypes capable of detecting a covert release of a biological pathogen by monitoring non-traditional data sources such as animal sentinels, aggregate and anonymized human behavioral indicators, and aggregate and anonymized non-diagnostic and other medical information – such information is statistical and unrelated to personal transaction data. Technical challenges include determining the value of each data source, alone and in combination with others, for earlier outbreak detection, correlating/integrating information derived from heterogeneous data sources, development of autonomous signal detection algorithms with high sensitivity and low false alarms, creation of disease models for autonomous detection, and maintaining privacy protection while correlating depersonalized data sources. The program is identifying, securing and characterizing nontraditional and "gold standard" data sources; developing advanced fusion and detection algorithms and disease models, identifying abnormal health indicators, and processing existing human, agriculture, and animal health data sources to determine the most viable indicators for abnormal health conditions. The program has performed analyses on simulated events to determine which algorithms are most valuable to detect bio-terrorist releases, in addition to its analysis of real world outbreaks for correlation of disease. Dynamic privacy protection that could be placed in a medical data system and ensure the anonymity of individual records are being developed and tested.

(U) A prototype bio-surveillance system has been constructed for cities of high military interest area such as the National Capital Area and one is also being developed for Norfolk, VA. They will show their value through monitoring surrogates for terrorist pathogens, which manifest themselves in early stages as non-specific, flu-like illness. They may also be demonstrated in a series of field experiments by injecting simulated biological event data into the real-time data streams of the testbed system. The Bio-ALIRT program will dramatically increase DoD's ability to detect up to two days earlier using existing data sources a clandestine biological warfare attack, involving both natural and unnatural pathogens, in time to respond and avoid potentially thousands of casualties. These technologies will be tested and integrated into the Total Information Awareness (TIA) network funded in PE 0603760E, Project CCC-03.

(U) Program Plans:

- Collect and analyze historical epidemiological data for routine diseases that are surrogates for military-interest pathogens, and also in order to model them as normalcy models against which to measure disease spikes.

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- Develop a biosurveillance system, identify components, and apply these capabilities in a system to detect disease and possible biological attack activity within the National Capital Region and the Norfolk area.
- Identify, access, and analyze additional data sources that may provide earlier indications of biological attack. Characterize promising data sources in different locations over different outbreaks to refine their value as early indicators.
- Refine emulation environment with updated data sources, sensors, data monitoring software models, and detection algorithms.
- Develop data fusion and signal detection algorithms with high sensitivity and specificity.
- Develop privacy protecting algorithms for the integration of heterogeneous data systems that will prevent re-identification of depersonalized data.
- Develop an integrated biosurveillance prototype in a permissive environment (e.g., military base) to determine if more invasive but appropriate means of detection will produce earlier warnings of outbreaks.
- Develop computer simulation environment to emulate bio-terrorist events and impacts on agricultural, animal and human populations.
- Transition data sources and algorithms to existing and developing medical surveillance systems and publish characterized data sources in the literature.

	FY 2002	FY 2003	FY 2004	FY 2005
Genisys	0.000	6.964	7.241	8.588

(U) The Genisys program is producing technology to enable ultra-large all-source information repositories to prevent terrorist attacks on the citizens, institutions, and property of the United States and its allies. The overall goal is to make databases easy to use and easy to populate to increase the level of information coverage, get answers when needed, and share information between agencies faster and easier. To predict, track, and thwart, or at least mitigate attacks, the U.S. needs full-coverage databases including information about all potential terrorists and possible supporters, terrorist materials, training/preparation/rehearsal activities, potential targets, specific plans, and the status of our defenses. Current database technology is far too complex, inflexible, and non-scalable to address the need to integrate all relevant existing databases and information sources, to automatically populate new repositories and to enable the easy creation of new information systems which today exist only in manual form. Only a small fraction of the critical information in the world is stored in a database. If we rely on current commercial database technology, building the new databases we need to combat terrorism will take decades. Today's database technology was defined in the 1970s, but processors, disks, and networks are now thousands of times more capable. Genisys will reinvent database technology to meet today's needs and capabilities.

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Genisys will also stress-test research ideas by developing a series of increasingly powerful leave-behind prototypes so that the intelligence community can get value immediately and provide feedback to focus research. These technologies and components will feed into the Total Information Awareness (TIA) network, which in turn supports the U.S. Army Intelligence and Security Command (INSCOM) in addition to other intelligence organizations to be determined.

(U) Program Plans:

- Develop new counter-terrorism systems by eliminating the need to design databases before using them.
- Simplify the use of databases by eliminating the need to know their internal structure (schema).
- Increase the level of coverage with new methods to auto-populate databases from web content, text, and multimedia information.
- Ensure personal privacy using anonymization, filters, inference control, and immutable audit.
- Automate database integration by developing a database schema crawler and schema translator --- enable fast cross-agency data sharing.
- Improve performance with technologies to automatically restructure databases.
- Create, test, and experiment with a prototype repository that integrates five or more existing databases and semi-structured information sites.

	FY 2002	FY 2003	FY 2004	FY 2005
Genisys Privacy Protection	0.000	3.921	3.982	5.900

(U) The Genisys Privacy Protection Program will create new technologies to ensure personal privacy in the context of increasing data analysis for detecting, identifying and tracking terrorist threats. Information systems and databases have unique potential to aid in identifying potential terrorist signatures. At the same time, Americans are rightfully concerned that the way this data is accessed and analyzed by investigators could threaten their personal privacy. The Genisys Privacy Protection program seeks to enable security with privacy by providing critical data to analysts while controlling access to unauthorized information, keeping personal identity information separate from non-personal data, and ensuring that any misuse of data can be detected and addressed. This program emphasizes the analysis of information, not people, and seeks to prevent access to personal information that may have inadvertently been collected during the lawful collection of information by the intelligence community. Access control and recordkeeping will be automated using business rules that translate policy directly into consistent computer

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processes to provide immutable audit data. This will be accomplished using hardware appliances that can be examined and understood by a third party not affiliated with analysts or investigators (an auditor). To reduce the problem of aggregating information from multiple sources, the Genisys Privacy Protection program will develop statistical and logical inference control systems to analyze queries and provide investigators access to information they need for analysis, while hiding identity and other sensitive data. Finally, Genisys Privacy Protection will create methods and prototype systems that guarantee that audit data cannot be changed, and will also automate the analysis of log data, identifying many types of potential privacy violations so that they can be properly addressed. These technologies will be tested and integrated into the Total Information Awareness (TIA) network funded in PE 0603760E, Project CCC-03.

(U) Program Plans:

- Develop privacy algorithms that prevent unauthorized access of sensitive identity data based on statistical and logical inference control.
- Develop roles-based rules for distinguishing between authorized and unauthorized uses of data and automate access control.
- Improve the performance of algorithms for identify protection.
- Develop algorithms for limiting inference from aggregate sources.
- Develop mechanisms and a trusted guard for access control and immutable audit.
- Improve the performance of identity protection algorithms and immutable audit.
- Create methods to automate audit, identify potential privacy violations, and uncover underlying goals and information content from obscure and distributed query sets.
- Develop new information security technologies to ensure personal privacy of U.S. citizen data and confidentiality of intelligence sources and methods. Examples include:
  - -- Increasing privacy and confidentiality by providing critical data to analysts while controlling access to unauthorized information.
  - -- Keeping individual identities separate from transaction and intelligence data.
  - -- Ensuring that any misuse of data can be detected and addressed.

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	FY 2002	FY 2003	FY 2004	FY 2005
Mis-Information Detection (MInDet)	0.000	3.000	5.000	12.000

(U) The objective of the Mis-Information Detection (MInDet) program is to reduce DoD vulnerability to open source information operations by developing the ability to detect intentional mis-information and to detect inconsistencies in open source data with regard to known facts and adversaries goals. A secondary output of the program could be evaluation techniques for use in planning information operations. These technologies will be tested and integrated into the Total Information Awareness (TIA) network funded in PE 0603760E, Project CCC-03.

(U) Program Plans:

- Develop domain specific indicators of potential intentional mis-information in open source material using "Red-Team" wargaming techniques and expert knowledge.
- Explore combinations of techniques from linguistic genre analysis, learning with background knowledge, business process modeling, and adversarial plan recognition for detection of intentional mis-information in open sources.
- Develop promising algorithms using a number of approaches (such as combination of linguistic processing, knowledge-based reasoning, and Bayesian Inferencing; decision-tree approach to detect red-flag conditions; deductive anomaly detection; Bayesian technique for evidence fusion; and categorization and concepts extraction) to detect mis-information.
- Demonstrate the ability to detect mis-information in a number of domains such as identifying misleading information in resumes, detecting inconsistencies in news releases between internal and external consumption, classification performance of detection effectiveness and computational resources from known fraudulent/suspicious company websites, and detecting red-flag conditions in SEC filings.
- Demonstrate ability to detect misinformation in open intelligence sources.

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	FY 2002	FY 2003	FY 2004	FY 2005
Activity Recognition and Monitoring (ARM)	0.000	0.000	5.500	9.500

(U) The Activity, Recognition and Monitoring (ARM) program will develop an automated capability to reliably capture, identify and classify human activities in surveillance environments. Currently, these types of activities are identified and analyzed by humans studying real-time and recorded video sequences. ARM technology will dramatically improve the speed and ability to discover and identify anomalous or suspicious activities. Situations where ARM technology will significantly improve current surveillance capabilities include monitoring crowds, searching for unusual patterns of activity, discovering unattended packages and identifying individuals who are casing, loitering, or observing critical facilities. In particular, this includes detecting hostile operatives collecting data on deployed forces, critical infrastructure components, or DoD facilities at home or abroad. The capability to automatically identify and classify anomalous or suspicious activities will 1) greatly enhance homeland defense initiatives by providing increased warning for asymmetric attacks, and 2) increase the reconnaissance and surveillance capabilities for Intelligence and Special Operations Forces. The bases of ARM capabilities will be human activity models. From human activity models, ARM will develop scenario specific models that will enable operatives to differentiate between normal activities in a given area or situation and activities that should be considered suspicious. ARM will develop technologies to analyze, interrupt, model and understand human movements, individual behavior in a scene, and crowd behavior. The approach will be multi-sensor and include video, agile sensors, low power radar, infrared, and radio frequency (RF) tags. The program will produce component technologies, and proto-systems for demonstrating and evaluating performance for multiple scenarios. ARM is a new program for FY 2004 that arose from new research areas identified in the Human ID at a Distance Program. These technologies will be tested and integrated into the Total Information Awareness (TIA) network funded in PE 0603760E, Project CCC-03.

(U) Program Plans:

- Develop intelligent activity and monitoring algorithms that are resident in networked sensors.
- Develop a proto-system of networked sensors that is scalable and extensible.
- Demonstrate and evaluate the proto-system on a series of increasingly challenging scenarios.
- Create a database capable of searching observed activities for retrospective analysis.
- Develop human computer interfaces that are tailored to the demands of different users.

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	FY 2002	FY 2003	FY 2004	FY 2005
Futures Markets Applied to Prediction (FutureMAP)	0.000	0.000	3.000	5.000

(U) The Futures Markets Applied to Prediction (FutureMAP) program will develop market-based techniques for avoiding surprise and predicting future events. Strategic decisions depend upon the accurate evaluation of the likelihood of future events. This analysis often requires independent contributions by experts in a wide variety of fields, with the resulting difficulty of combining the various opinions into one assessment. Market-based techniques provide a tool for producing these assessments. Applications include analysis of political stability in regions of the world, prediction of the timing and impact on national security of emerging technologies, assessment of the outcomes of advanced technology programs, or other future events of interest to the DoD. The rapid reaction of markets to knowledge held by only a few participants may provide an early warning system to avoid surprise. These technologies will be tested and integrated into the Total Information Awareness (TIA) network funded in PE 0603760E, Project CCC-03.

(U) Program Plans:

- Define and develop prediction markets for events of interest to DoD.
- Define and develop markets for early warning/alarm.
- Develop software and systems for creating, managing and analyzing prediction markets.

	FY 2002	FY 2003	FY 2004	FY 2005
Scalable Social Network Analysis Algorithms	0.000	0.000	3.348	4.040

(U) The Scalable Social Network Analysis Algorithms program will provide a structure to allow the analysis and visualization of linkages of a large number of individuals with associations of memberships in multiple, overlapping, structured organizations and in multiple types of interactions. The program will develop algorithms and data structures for analyzing and visualizing the social networks linkages, implement Algorithms and data structure into software modules that provide social network analysis functionality, and demonstrate this module across the TIA network in a real operational environment. It will focus on developing libraries of social network models that distinguish between terrorist organizations and normal organizations that may on initial superficial examination appear similar in structure.

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(U) Program Plans:

- Develop scalable algorithms and the data structures essential to support the analysis of social networks comprised of large number of individuals who may be linked by a multitude of interactions.
- Explore techniques in graph theory, social network analysis, and mathematics to identify networks of multiple relationships among individuals and/or organizations in open source materials.

	FY 2002	FY 2003	FY 2004	FY 2005
Rapid Analytical Wargaming (RAW)	0.000	0.000	7.500	9.360

(U) The Rapid Analytical Wargaming (RAW) program will develop a faster than real-time analytical simulation to support U.S. readiness for asymmetric and symmetric missions across operational, analytical and training domains. The program will develop technologies to generate a full spectrum of known and emergent behaviors that will expand existing tools developed for more conventional conflict simulation to more realistically portray and project today's asymmetric threats. These technologies will be validated against both historical and real-time world events. These technologies will be tested and integrated into the Total Information Awareness (TIA) network funded in PE 0603760E, Project CCC-03.

(U) Program Plans:

- Establish operational testbeds in conjunction with one or more transition partners (DIA and Joint Staff).
- Derive scalable abstract behavioral framework baseline to facilitate the identification and reuse of key military concepts across a broad context and multiple force structures and missions.
- Integrate predictive and descriptive models of existing terrorist individuals and groups into the abstract behavioral framework.
- Develop hybrid gaming technologies that rapidly generate known and emergent behaviors and decisions for asymmetric scenarios based on historical and current context.
- Test initial gaming technologies against both existing analytical tools and recent real-world scenarios.

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	FY 2002	FY 2003	FY 2004	FY 2005
Deception	0.000	1.700	2.456	3.335

(U) The Deception program will develop and demonstrate techniques and sensors to detect deceptive intent during personnel screening for: a) airport screening, b) personnel screening for intelligence and law enforcement agencies, and c) prisoner interrogation. The program will also explore new approaches to develop a scientific basis for understanding human deceptive processes which may lead the way to broad range deception detection applications.

(U) Program Plans

- Determine if high-stakes deceptive behavior can be detected at checkpoints through the discovery of identifiable characteristics of a high stakes target that make him or her stand out from ordinary people even in the presence of clutter and a wide range of subjects.
- Develop insight into the brain/body processes of deception by exploring deep brain processes that may be associated with deception, cultural biases and potential conditioned responses in deceptive situations.

	FY 2002	FY 2003	FY 2004	FY 2005
Counter Suicide Bombers	0.000	1.000	5.000	7.500

(U) The Counter Suicide Bomber (CSB) program will develop and demonstrate collections of technologies which can be used to search for, detect, track, and accurately identify suicide bombers at significant distances and times prior to attack to allow their neutralization with minimal collateral damage. Technologies will focus on remote biometrics to analyze and detect anomalous physiological and psychological behavior, and/or remotely match profiled behavior of known terrorists. The likelihood of a suicide bomber attack in a dense civilian location (e.g., shopping mall or stadium), in CONUS is of increasing concern. Current detection techniques focus on "sniffing" for explosives and other materials, but the bombers' modus operandi is becoming increasingly clever and nefarious, and may make success of such technical means more problematic. It may be more difficult to conceal psychological and physiological behavior of a bomber imminently close to his or her objective. Remote detection of such behavior could potentially push the neutralization radius out to a location where counteracting the bomber would result in minimal collateral damage, even if the device were to detonate.

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(U) Program Plans:
- Initiate physiology/psychology studies to develop detection/identification requirements.
- Develop CSB system concepts from requirement studies and initiate designs.
- Select demonstration system designs and begin component development.
- Perform demonstration experiments in realistic/operational environments.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Language Translation ST-29	0.000	43.432	57.201	55.883	65.767	65.945	66.196	65.826

(U) Mission Description:

(U) This project will develop and apply new software database management, human language and computer interaction technologies to provide fundamentally new capabilities of critical importance for a wide range of national security needs. This will enable advanced information technology to (a) automatically exploit large volumes of speech and text in multiple languages; (b) revolutionize human-computer interaction using spoken and written English and foreign languages; (c) more effectively accomplish computing and decision-making tasks in stressful, time sensitive situations; and (d) become active, autonomous agents/assistants to the warfighter by collecting, filtering, synthesizing and presenting information in a timely and relevant form.

(U) Most of the programs being funded in this newly created project were previously funded in project ST-11 under this program element. Given the growing importance of automated language translation and speech and text manipulation, a separate project solely for these efforts was considered a necessity.

(U) Program Accomplishments/Planned Programs:

	FY 2002	FY 2003	FY 2004	FY 2005
Situation Presentation and Interaction	0.000	8.770	10.869	7.500

(U) There are two programs involving *human-machine* communication.

- The Babylon program is providing the tactical warfighter with real-time, face-to-face speech translation during combat and humanitarian operations in foreign territories. The program addresses domain-specific translation accuracy and response time. Early prototypes of Babylon technology relying on simple dictionaries and phrases have been deployed on a test basis to Afghanistan. Future versions will offer more sophisticated, flexible and fluid translation and paraphrasing capability that will be more robust and conducive to normal human conversations.

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- The Symphony program is an applied follow-on effort to the Communicator Program, funded under project ST-11, emphasizing technology transition to the military, adaptability and scalability of the Communicator Galaxy Architecture for automatic dialogue in support of C2 (Command and Control) applications. Technologies to be emphasized include human stress adaptation, prosody, and system reliability in military environments. The program will centerpiece six technology insertion projects supporting all services and one commercial application.

(U) Program plans:

– Babylon.
  -- Establish baseline hardware design for handheld translation technology.
  -- Upgrade DARPA one-way technology to limited two-way translation.
  -- Obtain initial software decision approvals for full-featured DARPA two-way translation.
  -- Conduct multi-lingual data collection in Pashto, Dari, Farsi, Arabic, and Mandarin for contingency operations.
  -- Produce prototype handheld devices for field evaluations and acceptance.
  -- Perform initial coordination with U.S. Army PM Soldier for software integration into land warrior Block III (version 3.0).
  -- Integrate speech recognition engines into natural language parsers and translators.
  -- Distribute multilingual corpus to R&D community.
  -- Receive feedback from evaluators on DARPA two-way technology (deliver patches and fixes); units remain in operational use.
  -- Deliver upgraded handhelds (capable of supporting two-way technology) to software developers.
  -- Deliver alpha versions of DARPA two-way software for initial user testing.
  -- Select set of foreign languages for final development.
  -- Populate language digital resource repository at Defense Language Institute (DLI).

– Symphony.
  -- Develop FA-18 aircraft maintenance mentor prototype to enhance flight mechanic methods.
  -- Develop the Battlefield Casualty Reporting System (BCRS), a dialogue driven process to allow casualty reporting and sworn statements to be collected, automated validation and direct reporting to DA (Decision Authority) notification officials.
  -- Develop a ship based command and control system to allow officers and crew to query ship system status from any location on the ship, set an alarm for a future change in status, or launch agents to monitor particular sub systems.

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-- Create a complete dialogue based interface for all major Total Information Awareness (TIA) Systems to support system navigation and analytical processes; augment search parameters and dialogue based mentoring to assist the novice analyst or enhance the experienced analyst.
-- Conduct a vehicle navigation effort that focuses on the on-the-move environment attacking dialogue base capability in tactical vehicle noise, for the purposes of navigation, command and control and logistical support.
-- Initiate evaluation of dialog technologies for the Institute of Justice for use in multilingual detention facilities.

	FY 2002	FY 2003	FY 2004	FY 2005
Automated Speech and Text Exploitation in Multiple Languages	0.000	34.174	46.332	48.383

(U) There are three programs involving *human-human* communication. These technologies will be tested and integrated into the Total Information Awareness (TIA) network funded in PE 0603760E, Project CCC-03.

- The Translingual Information Detection, Extraction and Summarization (TIDES) program is revolutionizing the way time-critical intelligence is obtained from speech and text by developing technology to enable English-speaking operators and analysts to exploit the huge amounts of foreign speech and text available electronically but currently unexploitable due to vast volumes and insufficient foreign language skills. TIDES is creating powerful new capabilities for Detection (finding or discovering needed information), Extraction (pulling out key information), Summarization (substantially shortening what a user must read), and Translation (converting foreign language material to English). This will dramatically increase the quantity, quality, and timeliness of analysis and reporting by providing vital information to senior decision makers and enabling commanders to carry out critical missions.

- The Effective, Affordable, Reusable Speech-To-Text (EARS) program is creating powerful new automatic speech-to-text transcription technology whose output is substantially richer and much more accurate than currently possible. EARS will provide passive listening technology for critical languages and media for a wide range of national security applications. It will enable effective automated transcription from both broadcasts and telephone conversations.

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- The Global Autonomous Language Exploitation (GALE) program will develop techniques for discovering critical intelligence by autonomously exploiting enormous volumes of streaming speech and text from around the world (in many languages). GALE will enable machines to mine, refine, combine, and package information from broadcasts, conversations, newswire, and internet sources; discover trends and deviations; discern operator/analyst interest from their behaviors (actions and reports); and issue critical alerts, reports, and pointers whenever appropriate (without overwhelming), delivering information in actionable form to military operators and intelligence analysts without requiring them to request it. GALE will build off the successes of both TIDES and EARS.

(U) Program Plans:

– Translingual Information Detection, Extraction and Summarization (TIDES).
  -- Demonstrate capability to detect and track events described in English, Arabic, and Chinese news sources.
  -- Demonstrate capability to extract key information (about people, places, organizations, and relationships) from English, Arabic, and Chinese.
  -- Demonstrate capability to translate Arabic and Chinese documents into readable English.
  -- Define architecture for a unified text and audio processing (TAP) system that integrates various TIDES technologies.
  -- Transition TAP components to operational sites.
  -- Determine ability to port applicable TIDES technology to new languages.

– Effective Affordable Reusable Speech-To-Text (EARS).
  -- Develop automatic techniques to produce rich, readable transcripts of broadcasts and telephone conversations in English, Chinese, and Arabic.
  -- Substantially improve the word-error-rate performance of automatic transcription from approximately 50% down to 5-10%.
  -- Create automatic metadata extraction algorithms to enrich the resulting transcripts and to make them more readable.
  -- Create, demonstrate, and evaluate prototype EARS systems for producing rich transcripts from broadcasts and telephone conversations in English, Chinese, and Arabic.

– Global Autonomous Language Exploitation (GALE).
  -- Initiate multifaceted effort to develop techniques for discovering critical intelligence autonomously, exploiting huge volumes of streaming speech and text in multiple languages.

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	FY 2002	FY 2003	FY 2004	FY 2005
Center for Critical Languages	0.000	0.488	0.000	0.000

(U) Provides funding to assist in the development of a Center for Critical Languages.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Cognitive Systems Learning and Perception ST-30	0.000	10.595	14.822	58.846	102.743	122.139	117.140	107.272

(U) Mission Description:

(U) The Cognitive Systems Learning and Perception project will develop technologies that enable systems to learn and draw on their accumulated experience by applying knowledge gained through such experience to improve performance. These technologies will lead to systems demonstrating increased self-reliance, self-adaptive reconfiguration, intelligent negotiation, cooperative behavior, and survivability with reduced human intervention. Cognitive systems will comprise three primary types of processes: reactive, deliberative and reflective. Each of these will be improved through experimental learning. Reactive processes respond quickly and directly to known stimuli. Deliberative processes embody what is usually known as "thinking." Reflective processes (higher-order) allow a system to "step back" and evaluate the environment and their own capabilities to decide the next appropriate course of action. Different types of learning will improve all of these processes. Capabilities developed in this project include skill learning, pattern detection, and language learning, all of which will extend fundamental computing capabilities.

(U) A remarkable and unique aspect of natural perceptual systems is their ability to take an inordinate amount of raw sensor data, such as visual flow and rich auditory input, filter and integrate that data, and almost instantaneously unify the resultant data into meaningful elements. The human brain is able to create from this information perceptual units that parcel the world into objects and discrete entities that are then recognized, remembered, and used in problem solving. Looking closely at these innate perception abilities will yield insights into how to build totally novel computational systems that notice important, low-frequency events. This kind of approach should lead to dramatic improvements in the abilities of computers to process and analyze huge amounts of data to form a high level understanding within their environment.

(U) In the real-time environment of military operations, networks and systems that can automatically adapt to maintain their critical functionality, and improve these responses over time, will be crucial to operational success. These technologies will make the difference between mission degradation or failure and mission success in the event of cyber-attack or component attrition resulting from kinetic warfare or accidental faults and errors. Systems that learn will reduce the requirement for skilled system administrators and dramatically reduce the overall cost of system maintenance. As the military moves towards a sleek, dynamic expeditionary force, it is critical for systems to be more self-sufficient.

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(U) Program Accomplishments/Planned Programs:

	FY 2002	FY 2003	FY 2004	FY 2005
Adaptive Networking	0.000	3.291	5.000	12.700

(U) The Adaptive Networking program will create information and communication networks that possess significant degrees of network self-reliance and responsibility for their own behavior and survival. This includes unprecedented capabilities of self-diagnosis, automatic adaptation to changing and hostile environments, and reconfiguration in response to changes in environment, intelligent negotiation for tasks and resources, and robustness under attack. The project will produce a potentially radical and redesign of distributed computer and device networks and the software that manages them, and will have considerable ability to adapt to unforeseen changes.

(U) Program Plans:

- Identify and characterize the major components of an adaptive/cognitive network and software functionality for large-scale redesign.
- Develop a detailed architectural plan to implement adaptive, self-diagnostic and reconfiguration network capabilities.
- Design and develop a broad collection of specific cognitive network protocols and network management software for automatic statistical diagnosis control.
- Design and implement the experimental cognitive physical network infrastructure.

	FY 2002	FY 2003	FY 2004	FY 2005
Perceptive Assistant that Learns (PAL)	0.000	7.304	8.822	36.146

(U) The Perceptive Assistant that Learns (PAL) program, formerly the Intelligent Micro-Systems Technology program, will build upon prior DARPA programs that developed improved Human Computer Interactions and Highly Responsive computing programs to develop technology for a new class of integrated, highly functional cognitive systems. These systems will act as personalized executive-style assistants to knowledge workers and decision-makers (including military commanders). Initially the program will strive to create assistant programs that will display basic competencies, including interaction with people and other assistant programs in a normal office environment; sending and receiving information in

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a human-like manner; relating office information and activities in various different media; observing the assistant's user and inferring preferences and how to do useful procedures; and accepting advice and guidance expressed naturally in language. Such systems will push the limits of technology for formal reasoning, learning, and computational perception, all integrated in a unified multitasking, mixed-initiative architecture.

(U) The program will demonstrate cognitive systems that make use of past experience and knowledge to help the system understand and seek perceptual input, resulting in systems that do purposeful perception (i.e., sensor information will be filtered and processed to serve specific, high-level goals). Methods for processing raw data will be learned in a way that optimizes performance of the entire system. A unique feature of the PAL program will be the creation of technology for "Lifelogs," ontology-based systems that capture, store, and make accessible the flow of one person's experience in and interactions with the world.

(U) Program Plans:

- Develop baseline architecture for a complete PAL system.
- Develop initial knowledge base representing PAL's knowledge of domain of interest.
- Demonstrate continuous teaming capability over a protracted period of time.
- Develop technology for PAL system to observe user's activities overtime and develop understanding of user's preferences and basic office procedures.
- Develop mixed-initiative technology that enables PAL to ask appropriate questions at appropriate times when confidence in an inference is below threshold.
- Integrate data capture and manual/user-assisted metadata generation capabilities, data storage, and search engine interface to implement a baseline LifeLog capability.
- Establish benchmark tasks for purposeful perception. The benchmarks will include tests of classifying human activities, detecting unusual events, information filtering, and overall system performance.

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	FY 2002	FY 2003	FY 2004	FY 2005
Real-World Learning Technology	0.000	0.000	1.000	10.000

(U) The Real-World Learning Technology program will investigate advanced machine learning techniques and design and develop practical technologies to allow cognitive computing systems to improve their performance and understanding over time. The program will determine which types of learning (e.g., learning by example, learning by analogy, statistical learning from training data, explanation-based learning, etc.) are most effective when applied to challenging problems of importance to the military. It will drive the design and implementation of new, hybrid learning technologies that allow cognitive systems to learn in a wider variety of situations; among other things, these new methods will combine statistical learning techniques with knowledge-based techniques that take into account background knowledge and prior experience. Technologies that allow enduring systems to learn continuously over long periods of time will be developed. Application of this technology will have a dramatic effect on the adaptability and effectiveness of cognitive systems and their ability to perform better over time.

(U) Program Plans:

- Select several critical problems and scenarios to challenge machine learning technology in ways that will determine the essential value of individual techniques.
- Classify a broad variety of problems into classes best addressed with different types of learning technology and determine the most powerful and comprehensive sets of techniques that complement one another.
- Design and develop hybrid learning systems that allow cognitive systems to adapt to a wide variety of naturally-occurring situations and perform better over time against challenges similar to those to which they have been exposed in the past.
- Develop new technologies to address gaps exposed by the above analyses.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Communications, Interaction and Cognitive Networks ST-31	0.000	29.264	42.177	54.433	56.069	49.833	58.570	58.512

(U) Mission Description:

(U) The Communications, Interaction and Cognitive Networks project will dramatically improve warfighter effectiveness by developing revolutionary methods for users to interact with and direct cognitive systems (and the physical sensors and effectors they control) and for large-scale collections of cognitive systems to interact with one another in support of user objectives. Specifically, this project will develop technologies for creating systems capable of instruction, guidance, and persuasion using all forms of natural communication; technologies to enabling systems to detect and assess the user's cognitive state and adapt to optimize understanding and effectiveness of the user; and high-level languages for rapid but precise specification of complex behavior in response to mission demands, such as configuration of sensor networks. Since it is equally important for the warfighter to understand the system as it is for the system to understand the user's intent, this project will develop technologies that give systems the ability to explain and reason about their behavior and actions affecting the external world. Finally, robust interaction among cognitive systems, legacy systems, and humans will require incorporation of advanced models and control of the network infrastructure that connects them to ensure adequate provisioning of quality-of-service under dynamic loads to meet mission requirements. These technologies, taken together, will greatly increase warfighter effectiveness by allowing the warfighter to focus on high-level mission objectives rather than low-level interactions with the system while at the same time ensuring that the warfighter maintains essential understanding of how (and how well) the system is implementing and responding to that high-level direction.

(U) Program Accomplishments/Planned Programs:

	FY 2002	FY 2003	FY 2004	FY 2005
Augmented Cognition	0.000	19.128	21.215	19.202

(U) The Augmented Cognition (AugCog) program focuses on developing technologies to augment the warfighter's cognitive capacity and capabilities. This research area seeks to significantly expand human capability by augmenting human cognition and performance in the way that

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weapons, vehicles, and sensors significantly extend human physical capabilities. The hypothesis of this emerging field is that recent impressive progress in neural science, computation, and miniaturization can now be leveraged to enable new concepts of warfare.

(U) The AugCog program will develop the means, devices, and infrastructure necessary to measure a subject's cognitive state in real time and then manipulate that state in order to greatly improve the performance of various functions in the human-machine interface paradigm. This program will develop the technology to integrate new digital devices that support memory, perception, and thinking, and link that support with the user's context state information to directly improve the overall cognitive performance of the warfighter in complex and operationally stressful conditions. The program will culminate in the development of a closed-loop human-computer interaction capability with the computer able to anticipate, predict, and augment the performance of the user. This technology will also focus on perceptual processing displays that exploit advances in neuroscience and perceptual processing technologies to invent, modify, and redesign devices that deliver information to the human perceptual system. The technology will enable extraction of relevant signal from extraneous background noise. The effort will design and build adaptive multimodal interfaces that improve the ability of the warrior to communicate on the battlefield and exploit all of the digital information currently available only in the static command environment. The long-term impact of this work will be to provide users with vastly expanded expressive power, interface flexibility and transparency, and greater overall utility and robustness of interaction with next-generation digital systems. The technologies developed under the Augmented Cognition program will revolutionize the way 21st Century warriors interact with computer based systems, advance systems design methodologies, and fundamentally re-engineer military decision making processes. This program was previously funded in project ST-19.

(U) Program Plans:

- Evaluate EEG, physiological sensors, and eye tracking technologies that will permit the detection of human cognitive state.
- Integrate physiological and cognitive sensor technologies into a suite of cognitive state "gauges" that will permit the detection and the manipulation of the cognitive state and achievement of order-of-magnitude improvement in human-machine interoperability.
- Demonstrate and evaluate methods to use multi-modal query of digital memory to augment cognition by rapidly re-setting context.
- Develop the technology to autonomously delegate routine or non-urgent tasks to the computer, freeing the user to attend to tasks that demands the user's attention.
- Identify of the underlying neural generators of cognitive state to predict performance under a variety of parameters, such as stress and attention.

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- Develop a set of conversational interruption strategies with cues that help bring a user back into the context of the interrupted task at the point where the user was interrupted.
- Develop a toolkit that allows on-line analysis of a user's self-regulatory mechanisms including sensory response, intentional augmentation of sensation, context updating, performance context tracking, and response and error monitoring.
- Design and demonstrate visual displays and rich audio interfaces to provide the foundation for developing adaptive displays that adjust to the person, task, or display device.
- Design and develop new mobile-adaptive multimodal processing techniques and interfaces concepts tailored to the user, task, and environment, testing their performance and usability advantages within multimodal systems developed in the program

	FY 2002	FY 2003	FY 2004	FY 2005
Collaboraive Cognition	0.000	1.973	7.803	18.616

(U) The Collaborative Cognition program will develop technologies to enable the design and implementation of collaborative agents in dynamic multi-agent environments. Agents should be able to cope with limited and/or noisy sensor information; limited communication capabilities; changing and unforeseen environments and other agents; and limited *a priori* knowledge of each other's capabilities. In contrast to most current systems that address collaboration and teamwork, this program will develop software for controlling agents capable of interacting with both friendly and adversarial agents, and operating in multiple domains and/or varying scenarios within the same domain. In particular, the software will be adept at controlling agents under previously unseen or unknown conditions. This work will explore revolutionary concepts for applying distributed agent technology, first to modeling and simulation systems, with the long-range goal of applying this technology to operational environments, delivering a leap ahead in the capability of intelligent systems. An out-growth of previous DARPA work such as Control of Agent-Based Systems (CoABS), the program can quickly and efficiently explore the application of innovative cognitive and behavior modeling approaches to intelligent agent systems.

(U) Program Plans:

- Develop a strategic control language to specify the behaviors of individual agents and teams of agents regardless of their low-level implementations.

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- Enable agent learning to improve performance against a team of adversaries after observing the team's behavior over an extended period of time, assuming that the adversary's behavior is fixed.
- Develop plug and play modules for cognitive processes and primitive behaviors and increase the intelligence of agents in simulation and autonomous systems.
- Create an ability for agents to monitor, assess and explain the situation in the environment to support autonomous and collaborative behavior with other agents and humans-in-the-loop.

	FY 2002	FY 2003	FY 2004	FY 2005
Self-Aware Peer-to-Peer Networks	0.000	1.502	7.313	16.615

(U) The Self-Aware Peer-to-Peer Networks program, an out-growth of the DARPA Networking program, will develop resilient, scalable sensor-computation networks with decentralized control. This technology will support battlespace awareness by enabling the self-formation of large ad hoc networks of sensors and computational elements within the severely resource constrained environment (power, bandwidth, stealth) of military operations while enabling networks to survive component failure, network intrusion, and the subversion of elements. This self-aware network of sensors and communication will provide a lifeline to the warfighter in the support of effective operations while automating the burdensome and distracting tasks of network deployment, configuration, and management.

(U) High level languages will be developed to map the user's mission plans, including geographical constraints and direct control of individual sensors into network control actions. The sensor networks will function as a distributed form of cognitive system, which dynamically control resources and renders implicit knowledge of itself and its environment. The cognitive network technology will provide on-demand sensing, imaging, and tracking with a prediction/planning capability to estimate the state and trustworthiness of network elements and communication links. Therefore as elements fail or are subverted, the Self-Aware Peer-to-Peer Network will control the graceful degradation for realistic sensing and prediction tasks. This technology will support a variety of networks of manned and unmanned systems.

(U) Program Plans:

- Define and develop cognitive representations, distributed agent coordination technologies, information fusion algorithms, network control language, and network benchmarks.

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- Integrate image recognition, adaptive RF sensors, advanced signal processing for scene analysis and information extraction from sensors.
- Develop a dynamic architecture that defines logic, belief representation, cognitive network protocols, and adaptive target recognition and negotiation techniques.
- Develop mathematical models and algorithms to synthesize intelligent, self-aware, self-forming networks allowing for distributed control.
- Initiate the development/demonstration of robust, secure, self-forming tactical networks.

	FY 2002	FY 2003	FY 2004	FY 2005
Network Modeling and Simulation	0.000	6.661	5.846	0.000

(U) The Network Modeling and Simulation (NMS) program develops software to enable the autonomous prediction, design and control of complex networks over a broad range of time scales, network sizes, composition and performance. New models and simulators will enable reliable and rapid planning, design, analysis and configuration of military and emergency networks with minimal manual intervention. This program was previously funded in Project ST-19.

(U) Program Plans:

- Develop a hybrid simulator integrating fluid and multi-fractal models. Achieve 100x scalability in network size, 50-100x speed in simulation over sequential techniques, for both wired and wireless networks.
- Implement measurement and simulation based, on-line prediction of core Internet, and border gateway protocol, stability and vulnerability, including that arising from virus propagation.
- Develop a simulator suitable for on-line network analysis and control, and scalable to tens of thousands of nodes.
- Demonstrate on line network controls including quality-of-service provisioning, and dynamic reconfiguration.
- Demonstrate 10 to 100 x improvements in time to field new protocols, fault and vulnerability diagnosis, over operator-intensive current techniques.

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- Transition simulation software to DoD clients including DISA, DMSO, FCS, Navy, Air-Force, JFCOM and other service agencies, for use in applications including infrastructure protection, rapid battlefield network design, and network management and control.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Cognitive Systems Foundations ST-32	0.000	13.528	25.833	58.552	61.450	73.283	78.094	82.892

(U) Mission Description:

(U) The Cognitive Systems Foundations project will develop novel system-level solutions through the intelligent integration of cognitive agent capabilities built on robust software and hardware infrastructure. Systems with humanlike capability will need to integrate the cognitive capabilities of reasoning, learning, explaining, ability to be advised, self-awareness and coping robustly with surprise. These aspects of intelligence will be combined in innovative and powerful ways using new cognitive architectures. Overall this element seeks to make fundamental scientific and mathematical improvements in our understanding of and ability to create information and computing systems. Cognitive systems may also form teams to achieve goals in a coordinated manner, exceeding the performance of individual systems or humans working alone. Current fragile commercial systems will have to either be enhanced or radically changed to support this revolutionary objective. The new cognitive foundations will extend beyond today's standard Von Neumann computing model.

(U) The military faces new aggressive and agile threats that have sufficient technical resources to mount sophisticated attacks using easily accessible commercial information systems. The pervasive nature of both the threat and their means drive the need for systems that are able to dynamically adapt, collect and assimilate large quantities of data, and remain robust under a large set of potential failure conditions and threats.

(U) Therefore, the plan is to develop, evaluate, prototype and demonstrate a set of promising concepts in the context of full-scale test-beds in realistic scenarios and environments. These technologies will achieve the goals of developing a computational system with "human-like" capabilities and enhancing humans to act with "machine-like" precision. The next transformational revolution for military force development will be the seamless integration of autonomous physical devices, computation software agents, and humans. Transition goals are military C^4ISR, particularly next generation network-centric systems and platform-specific information collection and processing systems in space, air, sea, and land.

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(U) Program Accomplishments/Planned Programs:

	FY 2002	FY 2003	FY 2004	FY 2005
Network-Centric Infrastructure for Command, Control and Intelligence	0.000	9.000	11.028	15.206

(U) The Network-Centric Infrastructure for Command, Control and Intelligence (NICCI) program is developing technologies to automatically create virtual work centers, called "habitats," that can bring together the right combination of people, computer systems, robots, and data to accomplish a specific set of tasks. These habitats can be dynamically reconfigured because they are aware of the interrelated combat conditions and the context of the environment. New technologies will be developed to allow the warfighter, at any level of command, to rapidly assemble a habitat that addresses the needs of a specific task e.g., geographic situation awareness, or command interfacing with teams.

(U) Program Plans:

- Demonstrate use of logical policy specifications to control tasking, resource allocation, and access privileges. Demonstrate ability to extend and revoke policies within and among habitats cooperating on a specified task.
- Demonstrate that a change in data definitions is automatically reflected in data mapping among 5-6 habitats cooperating on a task.
- Demonstrate ability to modify temporal aspects (e.g., frequency of update, mediated by situation) of updates to habitat information from legacy components/systems.
- Demonstrate policy and workflow management capabilities that are operating effectively, and automatically adapt to changes in policies, doctrine, or situational context in a dynamic, multi-layered system-of-systems environment.
- Demonstrate seamless interoperability between heterogeneous systems with the ability to remotely monitor, manage, and reconfigure services and resources. Demonstration will incorporate various communication infrastructures.

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	FY 2002	FY 2003	FY 2004	FY 2005
Self-Regenerative Systems	0.000	3.235	4.000	10.000

(U) The Self-Regenerative Systems (SRS) program will develop the basic precepts of representation, reasoning and learning that will form the scientific foundation for all such future systems. This program will conceive, design, develop, implement, demonstrate and validate architectures, tools, and techniques to field systems capable of adapting to novel threats, unanticipated workloads and evolving system configurations, by employing higher-level cognitive functions such as reasoning, deliberation, and reflection. These technologies will allow future information systems to be dramatically more robust, survivable, and trustworthy than today's systems. Beyond graceful degradation capabilities provided by fault- and intrusion-tolerance mechanisms developed in prior DARPA programs, SRS-enabled systems will be able to reconstitute their full functional and performance capabilities after experiencing an accidental component failure, software error, or even an intentional cyber-attack. Also, they will maintain their robustness and trustworthiness attributes even as they undergo growth and evolution in functionality and performance over time. Such a system will learn from its experience so it performs better tomorrow than it did today.

(U) Program Plans:

- Identify novel attacks and generalize and learn from specific attack events to form a defense against a general set of cyber-attacks and failures.
- Develop technologies to diagnose and assess damage, repair and recover from damage caused by accidental faults, software aging, or malicious activities and, generally, heal the system automatically.
- Develop information systems that can assess dynamic security risks and predicatively adapt their security posture to anticipated threat conditions; and adaptively balance performance and functionality with security.
- Demonstrate scalable data redundancy for network-centric military applications and infrastructure services and develop techniques for natural robustness via biological metaphors to counter vulnerabilities of monoculture in military information systems.
- Develop probabilistic assurance techniques and compos able assurance toolbox to validate self-regenerative properties of information systems.

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	FY 2002	FY 2003	FY 2004	FY 2005
Architectures for Cognitive Information Processing	0.000	0.000	5.280	18.346

(U) The Architectures for Cognitive Information Processing (ACIP) program is developing a new class of processing approaches, algorithms, and architectures to efficiently enable and implement cognitive information processing. ACIP will develop the fundamentals, framework and development environments, algorithms and architectures, and implementations that will provide the basis for and enable innovative and truly efficient cognitive processing. Current intelligent processing implementations depend on the use of existing numerically based architectures and/or standard software architectures, and therefore are implemented via algorithms and processing architectures that are ill-suited to cognitive processes. To realize the impact and promise of cognitive processing, approaches, algorithms, and architectures attuned to cognitive processing fundamentals and that efficiently implement unique cognitive structures need to be established. The ACIP program will establish cognitive processing capabilities that significantly advance the state of the art at all cognitive implementation processing levels – cognitive modules, cognitive systems, and underlying cognitive processing approaches, algorithms, and architectures to support efficient cognitive implementations. In order to focus and establish context for the ACIP program, ACIP will pursue focused in-context DoD mission areas for the development of ACIP concepts. ACIP will develop cognitive implementations that will span the areas of perception, reasoning and representation, learning, and communication and interaction to enable new classes of cognitive information processing applications that will enable an overall goal - systems that know what they are doing.

(U) Program Plans:

- Establish Cognitive Information Framework that will provide common cognitive development environments, tools, and evaluation methods for cognitive algorithm and architecture developments, providing an enduring cognitive basis for a broad set of domains and applications.
- Establish proof of concept and evaluate in-context cognitive application baselines based on current approaches and "best-possible" cognitive implementations on existing processor architectures.
- Characterize the role of reflective reasoning in a cognitive system that reacts effectively to stimuli and also uses deliberation to plan and solve problems.
- Establish and demonstrate a first generation living framework supporting cognitive approach implementation, algorithm development, and architectural evaluation.

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- Select and develop cognitive architecture(s) and in-context applications for cognitive architecture implementations, demonstration and developments.

	FY 2002	FY 2003	FY 2004	FY 2005
Visibly-Controllable Computing (VCC)	0.000	1.293	5.525	15.000

(U) The Visibly-Controllable Computing (VCC) program will leverage the research conducted under Cyber Panel and others to provide a new generation of computing systems that display for their users, their system critical status, provide effective tools for controlling systems critical operations, and enable the system to explain its operation (e.g., current goals, health status) in terms that are appropriate for human consumption. VCC will eliminate confusing and information-free error messages in favor of greater software reliability and, when errors occur, useful explanations. VCC technology will provide a high degree of confidence that computing resources are matched against the user's goals and are not under the control of other entities, as can easily be the case with conventional technology. VCC will revolutionize the security of general-purpose information systems and control the current epidemic of stealth attacks in which attackers take control of systems but legitimate stakeholders never notice.

(U) Program Plans:

- Demonstrate realistic dependency analysis techniques for the interactions between software components.
- Determine the feasibility of building visibly-controllable systems that reduce the occurrence of disruptive system behaviors that confuse users. Develop a collection of system prototypes exploring a range of near-term/long-term design, implementation, and capability tradeoffs.
- Augment current techniques to construct a framework for developing high-assurance behavioral specifications (including security policies) for visibly-controllable systems.
- Demonstrate self-explanation techniques in which systems explain their critical goals and progress towards goals in a manner that is palatable to a variety of human users.
- Demonstrate control mechanisms empowering users to direct their systems towards users' goals while making the system-level consequences of user actions clear in advance.

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(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Knowledge Representation and Reasoning ST-33	0.000	18.289	26.451	34.327	58.710	59.604	82.974	102.397

(U) Mission Description:

(U) The Knowledge Representation and Reasoning project is central to the creation of a new class of computational systems – Cognitive Computing Systems. These novel computer-based systems will reason, learn, and respond intelligently to things that have not been previously programmed or encountered. This will be accomplished by creating unique and powerful new abilities for computers to perceive and understand the world, and to reason intelligently with the results of this kind of perception. The real power of human information processing emanates from higher-level capabilities that use abstraction, mental simulation and planning, hypothetical reasoning, powerful language understanding and generation capabilities, and self-awareness. Pursuing the creation of new computational systems without an understanding of the architecture for doing such things would result in a continuation of current relatively unintelligent computational system development. This program will develop novel and effective technologies for representing knowledge of the world in computer-processable form. It will develop accompanying methods of reasoning (including deductive, abductive, planning, strategic, analogical, and flexible methods), which will give the next generation of cognitive computing system important foundations for dealing with real-world information complexity and uncertainty. Instead of pursuing the path of increasing raw computer speed and power, the project will develop approaches that allow computers to reason using explicit structures that represent their knowledge. This substrate of powerful representational capabilities will lead to computer systems being able to plan, solve problems, understand language, understand their own reasoning, and explain their thought processes. This project focuses on two groundbreaking research areas that will develop core cognitive capabilities essential to a cognitive information processing system.

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(U) Program Accomplishments/Planned Programs:

	FY 2002	FY 2003	FY 2004	FY 2005
Autonomous Software for Intelligent Control	0.000	14.545	9.085	0.000

(U) The Autonomous Software for Intelligent Control effort will program a variety of autonomous mobile robots to independently perform military tasks in a diverse spectrum of complex, dynamic environments. The goal is to achieve near-human performance in the tasks of perception-based autonomous vehicle navigation and effective interaction of robots with humans. Representations of tasks, goals, plans, common sense knowledge, and perceived environmental features, including the behaviors of humans, are core to this effort. Several alternative approaches are being pursued to augment pre-programmed activities and responses with powerful learning-derived competencies for perception and control analogous to those of biological systems. This software will enable autonomous systems to effectively reason about real-world situations in order to appropriately modify their behaviors. Integrated perception, including fusion of data from multiple sensor and multiple processing modalities of the same data will reduce operator intervention and achieve semi-autonomous operation. The result will be highly capable robots that can learn new tasks and adapt quickly to new environments with minimal programming effort, with numerous applications in the battlespace of the future. This program was funded in Project ST-19 in FY 2002.

(U) Program Plans:

- Demonstrate adaptive generation of complex behaviors; multi-sensor-enabled, outdoor navigation; and methods for directing perceptual attention.
- Develop and demonstrate an integrated robust on-road driving system capable of operating in the proximity of humans and other vehicles.
- Demonstrate a trainable, perception-based, autonomous navigation capability for robots in urban environments.
- Integrate perceptual, behavioral, and natural interactive capabilities onto a humanoid robotic platform, and measure the relative performance of human-supervised and autonomous behavior modes.
- Develop distributed perception-based autonomous navigation behaviors for unmanned surface vessels (USVs) and share information between multiple USVs, to achieve cooperative target tracking, interception, and self-defense.
- Demonstrate cognitively compatible teams of semi-autonomous, semi-independent robots, with adjustable operator interaction modes.

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- Develop infrastructure and tools to seamlessly integrate communications, control, and perception capabilities to implement a networked team of air and ground unmanned vehicles for reconnaissance and area patrol.

	FY 2002	FY 2003	FY 2004	FY 2005
Knowledge Based Systems	0.000	0.000	7.552	17.164

(U) The Knowledge Based Systems program will develop the enabling technologies, methodologies, ontologies, and specific knowledge bases to achieve the next generation of intelligent, knowledge-intensive systems. This work will focus on developing technology that spans the spectrum from large, strategic knowledge banks to personal knowledge pads. The program will develop enabling technologies for codifying, linking, integrating, accessing, and using complex and cross-disciplinary knowledge at widely varying scales. This capability at strategic level will provide DoD decision makers with rapid as-needed access to decision-relevant background knowledge from a broad spectrum of distributed sources. The knowledge will be expressed in formal knowledge representation languages that will allow computers to reason about the knowledge, consider its implications, imagine possible future scenarios, and discuss with the human user all aspects of the information. The significant challenges are centered on the fact that critical knowledge involves temporal information, complex belief structures, and uncertainty, and current representation technology is not adequate to capture such information. This program will also develop the technology needed to enable the creation of a personal knowledge pad which would capture (in a computer understandable form) knowledge of the user's daily tasks and activities. This effort would then provide the user with intelligent automated assistance to help the user plan and accomplish his daily activities and, over time, learn how the user accomplishes these tasks and provide increasingly valuable automated assistance.

(U) Program Plans:

- Develop knowledge module authoring tools.
- Develop methods, protocols, and tools for using interoperable knowledge modules resident on distributed knowledge servers.
- Develop an integrated knowledge representation and learning technology that enables effective representation of essential forms of knowledge. Document a substantial library of formal declarative interoperable multi-use ontologies initially across single, then multiple domains.
- Demonstrate and evaluate prototypes of strategic and personal knowledge-based systems.

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	FY 2002	FY 2003	FY 2004	FY 2005
Advisable Systems	0.000	3.744	9.814	17.163

(U) The goal of the Advisable Systems program is to design and build systems that users can control in natural and flexible ways – not via menus or by programming them, but by exchanging advice and instructions with them. "Advice" will span a spectrum ranging from high-level policy and goals to intermediate preferences and constraints on system behavior to specific direction and contingency actions. Users will be able to express this advice in natural English and engage in a dialogue to clarify/elaborate the general advice. Based on this dialogue, the system will translate the user's intent into an executable plan and start behaving as if it were originally programmed for that function. As Advisable Systems mature, this behavior will increase in complexity from configuration of existing capabilities to the automated acquisition or generation of new capabilities. Advisable Systems will furthermore continuously engage in natural dialogues with users as they encounter unforeseen circumstances or conflicts in priorities and standing orders, eventually becoming fully autonomous in their functioning as commanded. Although progress in this area will require initial focus on selected mission domains to constrain the dialogue, tools will be developed for adapting the technology to other domains. While natural language interfaces are an essential enabler for Advisable Systems, this project will not support speech recognition research per se (except where important conceptual gaps exist that would bear on successful expression of advice and explanations), but rather the development of dialogue management systems that allow systems to glean and clarify user intent. Advisable systems will allow commanders and other decision makers more natural and more productive access to and control over a wide range of software capabilities in a variety of mission-critical areas, including command-and-control, intelligence and logistics.

(U) Program Plans:

- Select two or three key mission domains and compelling scenarios to drive advisable systems research with a series of increasingly difficult challenge problems. Metrics for assessment include "programming" speed and length of dialogue necessary; correctness of resulting system behavior; and performance of the advisable system versus a hand programmed one.
- Develop domain-specific intermediate languages for expressing guidance/advice with precise operational and declarative semantics and tools for translating these languages into either executable plans or parameterized configurations of existing software modules.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Computing Systems and Communications Technology PE 0602301E, Project ST-33

- Develop a dialogue system with domain-specific semantics for eliciting natural language advice from the user. This dialogue system will translate user guidance into the precise intermediate languages described above for both implementation and verification of user intent. Tools for generating dialogue systems from arbitrary domain descriptions will be developed.
- Develop protocols and tools for applying policy preferences and constraints and mediating conflicts among them.

(U) Other Program Funding Summary Cost:

- Not Applicable.